CSS Long Term Control Plan Update Alternatives

Alternatives Evaluation: Tunnels

City of Alexandria, VA
Department of Transportation and Environmental Services

FINAL – October 2015

GREELEY AND HANSEN

Table of Contents

Table of Contents

Table of Contents

List of Tables

List of Figures

Attachments

Executive Summary

During a rain event, underground tunnels capture and store combined sewer overflow in the tunnel. After the rain event, the stored volume is sent to the wastewater treatment plant for a high level of treatment. Underground tunnels are a common and accepted technology for conveyance and storage of combined sewage overflows. Across the Potomac River, DC Water is currently constructing a series of underground tunnels to mitigate their combined sewer overflows. Many other communities have installed tunnels to address their combined sewer systems, including Atlanta, Boston, and Richmond.

The basic tunnel alternatives considered for the City's Long Term Control Plan Update (LTCPU) are described in Table ES-1. Tunnels that provide both storage and outfall relocation are considered.

Table ES-1
Tunnel Alternatives

Alternative	Name	Description
T1	Store and relocate CSO-003 and CSO-004 to AlexRenew	Divert flow from CSO-003 and CSO-004 into a tunnel that stores CSO flow and relocates excess CSO to a single pumped overflow at AlexRenew (CSO-002 addressed by other means).
T2	Store and relocate CSO-002, CSO-003, and CSO-004 to AlexRenew	Divert flow from CSO-002, CSO-003, and CSO-004 into a tunnel that stores CSO flow and relocates excess CSO to a single pumped overflow at AlexRenew. The current CSO-002 and CSO-003 overflow structure will remain as a relief for extreme wet weather events.
T3	Store and relocate CSO-002, CSO-003, and CSO-004 to the Potomac River	Storage tunnel capturing CSO-002, CSO-003, and CSO-004 for storage. Any CSO volume in excess of the tunnel will flow to the Potomac River north of the Wilson Bridge. CSO 002 and CSO-003 are maintained for extreme wet weather events.
T4	Store and relocate CSO-003 and CSO-004 to AlexRenew and relocate CSO-002 to the Potomac River	Two tunnels, one relocating CSO-003 and CSO-004 to AlexRenew (Alternative T1) and a second separate tunnel capturing CSO-002 only and conveying CSO-002 flow to the Potomac River north of the Wilson Bridge. CSO 002 is maintained for extreme events.

The tunnel storage and relocation alternatives for CSO-004 considered herein are generally consistent with the ongoing wet weather improvements work between the City, Fairfax County and Alexandria Renew Enterprises (AlexRenew); however, are upsized to include CSO-003 and are sized based on both storage and conveyance.

Tunnels remain a feasible and promising alternative when sizing criteria is based on capturing and retaining the CSO volume of the 5th largest storm in the typical year of 1984 (Scenario A). Table ES-2 summarizes the cost of the tunnel alternatives.

Table ES-2
Tunnel Capital Costs

Alternative	Scenario	Outfall Captured	Construction Cost	Project Costs	Land Acquisition	Estimated Capital Cost
T1	A	CSO-003/004	$44.0	$15.4	$1.1	$60.5
T2	A	CSO-002/003/004	$78.2	$27.4	$1.1	$106.6
T3	A	CSO-002/003/004	$84.7	$29.6	$3.3	$117.6
T4	A	CSO-002	$24.6	$8.6	$1.6	$34.8

Alternative	Scenario	Outfall Captured	Construction Cost	Project Costs	Land Acquisition	Estimated Capital Cost
T1	B	CSO-003/004	$108.9	$38.1	$1.1	$148.1
T2	B	CSO-002/003/004	$224.9	$78.7	$1.1	$304.7
T3	B	CSO-002/003/004	$255.4	$89.4	$3.3	$348.0
T4	B	CSO-002	$87.4	$30.6	$1.6	$119.7

When the sizing criteria is based on the 2004-2005 TMDL years, the volume requirements, space limitations, and capital costs make the tunnel alternative unfavorable and impractical for all outfalls.

It is recommended that all of the Scenario A tunnel alternatives be moved forward for scoring and ranking relative to the other alternatives.

The Scenario B tunnel alternatives are unfavorable and impractical due to the very large volume requirements, insufficient land availability, and extraordinarily high capital costs. It is recommended Scenario B tunnel alternatives be eliminated from further consideration.

Section 1 Overview

Tunnel facilities are commonly used to reduce overflows by capturing and storing combined sewage. After the wet weather event, the stored flow would be conveyed to the AlexRenew Enterprises (AlexRenew) Water Resources Reclamation Facility (WRRF) for a high level of treatment. Tunnel systems are being used in several other CSO communities to capture combined sewage, most recently in Washington, D.C. by DC Water.

The basic tunnel alternatives under consideration are described in Table 1-1. Tunnels for both storage and outfall relocation are considered.

Table 1-1
Tunnel Alternatives

Alternative	Name	Description
T1	Store and relocate CSO-003 and CSO-004 to AlexRenew	Divert flow from CSO-003 and CSO-004 into a tunnel that stores CSO flow and relocates excess CSO to a single pumped overflow at AlexRenew (CSO-002 addressed by other means).
T2	Store and relocate CSO-002, CSO-003, and CSO-004 to AlexRenew	Divert flow from CSO-002, CSO-003, and CSO-004 into a tunnel that stores CSO flow and relocates excess CSO to a single pumped overflow at AlexRenew. The current CSO-002 and CSO-003 overflow structure will remain as a relief for extreme wet weather events.
T3	Store and relocate CSO-002, CSO-003, and CSO-004 to the Potomac River	Storage tunnel capturing CSO-002, CSO-003, and CSO-004 for storage. Any CSO volume in excess of the tunnel will flow to the Potomac River north of the Wilson Bridge. CSO 002 and CSO-003 are maintained for extreme wet weather events.
T4	Store and relocate CSO-003 and CSO-004 to AlexRenew and relocate CSO-002 to the Potomac River	Two tunnels, one relocating CSO-003 and CSO-004 to AlexRenew (Alternative T1) and a second separate tunnel capturing CSO-002 only and conveying CSO-002 flow to the Potomac River north of the Wilson Bridge. CSO 002 is maintained for extreme events.

It is important to note that the relocation of CSO-004 and an associated conveyance tunnel was first conceived as part of a joint effort by Alexandria Renew Enterprises, the City of Alexandria, and Fairfax County to control wet weather flows, eliminate sanitary sewer overflows, and mitigate surcharging in the collection system. The concepts associated with Alternative T1, and portions of Alternatives T2 and T3 are generally consistent with the previous work; however, they are upsized to include CSO-003 and are sized based on both storage and conveyance.

Section 2 Components and Sizing

2.1 Tunnel

Most tunnels are round in shape and vary in diameter and length. The tunnel volume is estimated with simple geometry using the following equation:

$$Volume\ to\ Store = Length\ of\ Tunnel * \frac{\pi * Diameter^2}{4}$$

Potential tunnel construction methods are addressed in Attachment A, including the following:

- Conventional pipe jacking;
- Pipe jacking by tunnel boring machine (TBM), earth pressure balance machine (EPBM), or microtunnel boring machine (MTBM); and
- Utility tunneling with one or two-pass lining systems.

2.2 Dropshafts

Dropshafts are constructed for two main purposes:

- Conveying flow from the surface sewers into the tunnel; and
- Construction of the tunnel.

Dropshafts can vary in diameter depending on their purpose. Dropshafts that are only used to drop flows to the tunnel are typically smaller in diameter and are sized for the amount of flow that in necessary to drop. Dropshafts that are built for construction of the tunnel are typically larger in diameter than the tunnel. These shafts must be sufficiently large to accommodate the tunneling equipment as well as the tunnel sections that will support the tunnel.

Dropshafts also have some volume associated with them that will fill up with water when the tunnel is in use. Typically this volume is not taken in to account when determining the size of a tunnel because it provides only a small fraction of the volume required.

2.3 Dewatering Pump Station and Shaft

The dewatering shaft is located at the lowest point in the tunnel system. This shaft is where all the water in the tunnel will flow by gravity and where the flow will exit the tunnel system. At a minimum, this shaft will contain a dewatering pump station and screening facility. The dewatering pump station will remove the water from the tunnel once the sewer system or treatment plant can accept dewatering flow. The dewatering pump station will dewater the tunnel system in approximately 24-hours. The screening facility will prevent the dewatering pump station from getting clogged with debris.

2.4 Screening Facility

A screen facility is needed at the dewatering pump station to protect pumps from large objects that flow into the tunnel. The facility will pass flow through a bar rack screen with 2 to 3 inch screen openings before entering the dewatering pumps. There are several types of screens available. As an example, the Richmond McCloy tunnel utilizes a climber screen that uses endless track system with a gear-driven cleaning rake to carry screenings from the submerged bar rack to a discharge chute for removal without the use of chains, sprockets, cables. Other technologies include clamshell bucket cleaning devices that are lowered on cables or chains. A hoist lowers the clamshell to the bottom of the bar rack while collecting debris accumulated on the screen. The hoist then returns the bucket to the top of the shaft where debris is dropped into a hopper or dumpster for disposal. A more thorough evaluation of the type of screening facility needed will be performed if one of the tunnel alternatives is selected for further evaluation.

2.5 Wet Weather Pump Station

The AlexRenew WRRF is in the process of being upgraded with a Nutrient Management Facility (NMF). A part of the upgrade anticipates the final LTCPU to deliver more flow to the WRRF. The NMF construction project incorporates provisions for a Wet Weather Pumping Station (WWPS) to pump excessive CSO flow out of the relocated CSO-004 to help prevent basement backups. Use of the WWPS is described under each basic alternative below.

2.6 Sizing

Two scenarios were studied to size the storage tank facility to reduce CSO volume and frequency to meet the goal of the TMDL:

- Scenario A: Capture and retain the CSO volume of the 5th largest storm in the typical year (1984), for CSO outfalls 002, 003, and 004. Consistent with the presumption approach (i) of the National CSO Policy, which results in four overflows per year in the typical year.
- Scenario B: Capture and retain the CSO volume to achieve 80% (002) and 99% (003 and 004) bacteria reduction for the largest storm in the 2004-2005 TMDL period.

The Scenario B sizing is in strict accordance with the assumptions and requirements of the TMDL modeling. The TMDL modeling was based on 80% control for CSO-002 and 99% control for CSO-003 and CSO-004 during each day. Alternatively, Scenario B could be achieved on an annual basis with reduced sizing. For example, CSO-002 could be sized to capture 100% of most of the storms, but less than 80% of the really large storm event. As noted in the *Regulatory Requirements Technical Memorandum*, the City has repeatedly raised concerns with many of the assumptions associated with the TMDL modeling. The City believes the assumptions do not represent the actual nature of CSO impacts or an understanding of how CSOs are typically controlled.

2.6.1 Volume and Flowrate

The design volume and flowrates for each scenario are presented on Table 2-1 and are used to size the tunnel and confirm conveyance capacity.

Table 2-1
Storage Volume Required for CSO Outfalls for Scenarios A and B

	Unit	CSO 002	CSO 003 & 004
Scenario A overflow volume	MG	2.0	0.8
Scenario A CSO flowrate	MGD	16.6	11.0
Scenario B overflow volume	MG	25.4	17.6
Scenario B CSO flowrate	MGD	113.4	95

2.7 Disinfection of Tunnel Overflows

A combination tunnel/disinfection alternative comprising the flowrates under Scenario B and the tunnel sizing volume of Scenario B incorporates the following:

- Construction of Alternative T1 to the Scenario A volume and the Scenario B flowrates – which would not require significant changes to the tunnel aspects of Alternative T1 as the Alternative T1 sized for Scenario A volume will convey the Scenario B flowrates.
- For flows in excess of the Alternative T1 storage capacity that are pumped by the WWPS, construct a disinfection facility on the AlexRenew site to disinfect the Scenario B flows. This requires a 95 MGD facility. Note that the 95 MGD flowrate is used to address peak flow after the Alternative T1 tunnel is full.

The disinfection facility at AlexRenew for this purpose is estimated to be of similar size (0.6 acres) and cost ($35.8 Million) to that shown on Figure 1-8 of the *CSO Disinfection Technical Memorandum*. As shown on Figure 2-1, there is insufficient site in the vicinity of AlexRenew for such a facility. In addition, such a facility would operate intermittently and rarely at its design flow rate. Experience with mechanical and chemical systems that are not used on a regular basis indicates such facilities are unreliable. For these reasons, this option will not be considered further.

Figure 2-1
AlexRenew Vicinity Map with Disinfection

Section 3 Basic Tunnel Alternatives

3.1 Description of Alternatives

3.1.1 Alternative T1 – Tunnel Storage for CSO-003 and CSO-004 and Relocate CSO-004 to AlexRenew

Alternative T1 captures all flow from the current CSO-003 and CSO-004 and diverts those flows into a tunnel that stores and conveys the flow to the AlexRenew WRRF. Flows stored by the tunnel are pumped once the rain event has passed to the WRRF for treatment by a dewatering pump station. If the volume of flow from CSO-003 and CSO-004 is in excess of the storage capacity of the tunnel and/or treatment at the WRRF, excess flow is pumped by the WWPS to a relocated outfall at the WRRF.

Alternative T1 includes a tunnel that extends from the intersection of Duke Street and Daingerfield Road to the AlexRenew WRRF. An 8-ft diameter, 2,600-ft tunnel is needed to meet the requirements of Scenario A. An approximately 34-ft diameter, 2,600-ft tunnel is needed to meet the requirements of Scenario B. Under Alternative T1, CSO-002 is addressed by other means.

New diversion structures divert the flow from CSO-003 and CSO-004 to the initial dropshaft located at the intersection of Duke Street and Daingerfield Road (Shaft 1). The dropshaft is approximately 75-ft deep and the diameter depends on the diameter of tunnel selected. The tunnel starts at this location and continues south underneath Hooffs Run for approximately 1,800-ft at 0.50% slope where a turning shaft is located (Shaft 2). At this location Shaft 2 is approximately 80-ft deep. From there the tunnel continues south just over 800-ft to the terminus dropshaft (Shaft 3) at a final depth of approximately 90-ft. Shaft 3 contains the screening facility and the dewatering pump station to dewater to AlexRenew WRRF once the treatment plant has resumed normal operations following a wet weather event. Additionally at Shaft 3 the flow in the tunnel can be conveyed underneath Hooffs Run to Shaft 4 located near the WWPS. It can pump the flow to the relocated CSO-004 outfall when the tunnel and sewer system become overwhelmed during wet weather events that exceed the capacity of the tunnel and the sewer system. The WWPS will hold the hydraulic grade line of the tunnel system in order to prevent potential basement backups in the City. The location of the Alternative T1 infrastructure is shown on Figure 3-1.

Figure 3-1
AlternativeT1 Potential Tunnel Alignment

3.1.2 Alternative T2 – Tunnel Storage for CSO-002, CSO-003, and CSO-004 and Relocate CSO-004 to AlexRenew

As with Alternative T1, tunnel Alternative T2 captures all flow from CSO-003 and CSO-004 to be stored in the tunnel and conveyed to AlexRenew for treatment. In addition under Alternative T2, flows from CSO-002 up to the design volume of either Scenario A or Scenario B are also captured and conveyed to AlexRenew. Overflow volumes in excess of the storage capacity and/or treatment are pumped by the WWPS to a relocated outfall. Alternative T2 includes the tunnel as described in section 3.1.1 that extends from Duke Street to the AlexRenew WRRF. Additionally the tunnel continues from AlexRenew to the vicinity of CSO-002 where it intercepts overflows. Alternative T2 includes an upstream dropshaft at the intersection of Green Street and Royal Street (Shaft 6), an intermediate dropshaft located at the intersection of Green Street and South Patrick Street (Shaft 5), ends at the terminus Shaft 3. The potential alignment of this tunnel is shown in Figure 3-2. The proposed length of the CSO-003/004 tunnel plus the length of the CSO-002 tunnel is approximately 7,400-LF. An 8-ft diameter tunnel is needed to capture the 5th large storm in 1984; an approximately a 32-ft diameter tunnel is needed to capture 80% of CSO-002 and 99% of CSO-003/004 in 2004-2005.

Figure 3-2
Alternative T2 Potential Tunnel Alignment

3.1.3 Alternative T3 – Combine CSO-002, CSO-003, and CSO-004 and Relocate to the Potomac River

Alternative T3 is identical to Alternative T2 with one modification: instead of the WWPS pumping excess volume at AlexRenew into Hooffs Run, the tunnel is extended due east past Shaft 6 to the Potomac River where the WWPS pumps excess flow into the river. This alternative still stores the same volume of CSO as Alternative T2, however any flow in excess of the tunnel capacity overflows to the Potomac River instead of Hooffs Run and results improved water quality in Hooffs Run and Hunting Creek.

The tunnel extends due west from Shaft 6 (described in section 3.1.2) to the new wet weather pump station located on the shore of the Potomac River (Shaft 7). This alternative stores slightly more CSO volume than Alternative T2 due to the additional length and the overflow location during very large wet weather events is located at the Potomac River rather than Hooffs Run. A proposed alignment for Alternative T3 is shown in Figure 3-3.

Figure 3-3
Alternative T3 Potential Tunnel Alignment

3.1.4 Alternative T4 – Relocate CSO-002 to the Potomac River

Alternative T4 addresses CSO-002 by constructing a tunnel to store the overflows and during large wet weather events; flow in excess of the tunnel volume will overflow by gravity to a relocated outfall into the Potomac River. Under Alternative T4, CSO-003 and CSO-004 are addressed by other means.

Alternative T4 includes a tunnel that extends from the intersection of Green Street and Royal Street to the Potomac River. A 15-ft diameter, 1,700-ft tunnel is needed to capture the 5th large storm in 1984. An approximately 51-ft diameter, 1,700-ft tunnel is needed to capture 80% of the CSO in 2004-2005. Under Alternative T4, CSO-003 and CSO-004 are addressed other means.

The initial dropshaft (Shaft 6) is located at the new CSO-002 diversions structure at the intersection of Green Street and Royal Street. Included in Shaft 6 is a dewatering pump station to pump the tunnel back into the sewer system and to the AlexRenew WRRF once the wet weather event has passed. The tunnel heads due west at an upward slope of 0.50% for approximately 1,700-ft to the Potomac River where the upshaft (Shaft 7) will allow excess flow to overflow by gravity. The potential alignment for Alternative T4 is shown in Figure 3-4.

Figure 3-4
Alternative T4 Potential Tunnel Alignment

Alternative T4 is principally shown here as a tunnel. Alternatively, Alternative T4 could be installed as a series of relatively shallow storage boxes. This approached could loosely be considered a hybrid between tunnels and tanks, as it will provide both storage and conveyance. A similar approach was recently utilized in San Francisco. If Alternative T4 remains, it is recommend the storage box alternatives be considered further.

3.1.5 Sizing Summary

Table 3-1 summarizes the different tunnel diameters necessary to meet the conditions described above.

Table 3-1
Tunnel Diameter Summary

Alternative	Scenario A	Scenario B
T1	8-ft	34-ft
T2	8-ft	32-ft
T3	8-ft	32-ft
T4	15-ft	51-ft

3.2 Hydraulics

3.2.1 Hydraulic Control Points (HCP)

The hydraulics of each of the basic alternative are based on control points that establish how the tunnels are designed and operated. The control points are described in Table 3-2 with elevations in the NGVD 29 datum.

Table 3-2
Hydraulic Control Points

HCP	Description	Elevation
1	Hooffs Run design overflow elevation for the relocated CSO-003 and CSO-004 (T1, T2, and T3). 25-year flood elevation to prevent backups along the Commonwealth Interceptor.	11.0
2	Hunting Creek design overflow elevation for CSO-002 (T2) elevation that cannot be exceeded to prevent sewer backups along Royal Street.	3.0
3	Potomac River design overflow elevation for relocated outfall (T3 and T4).	3.0
4	Royal Street sewer crown (elevation that cannot be exceeded to prevent sewer backups along Royal Street)	5.0
5	AlexRenew maximum influent elevation (elevation that cannot be exceeded to prevent sewer backups along the Commonwealth Interceptor and Holmes Run Trunk Sewer)	-2.39

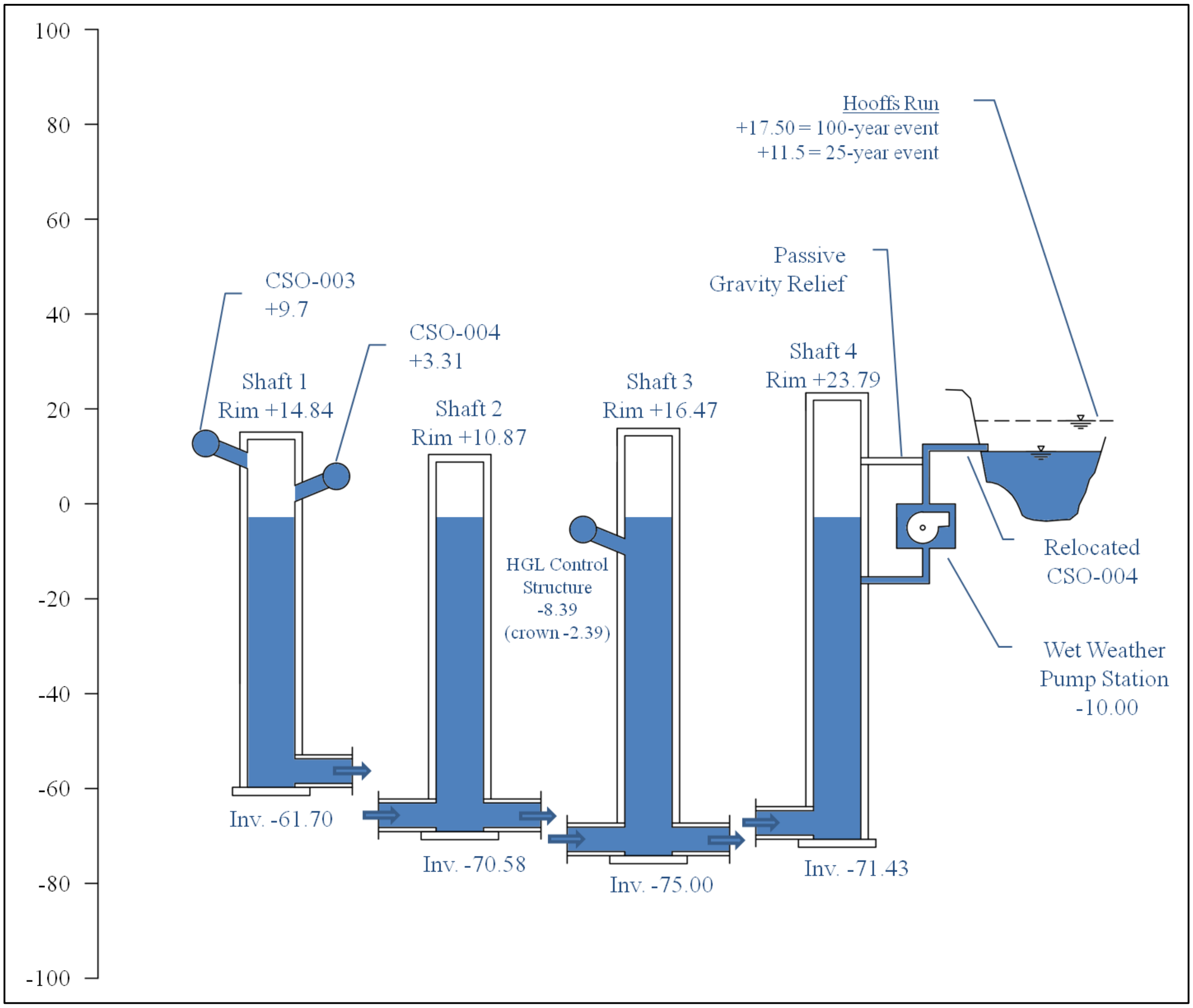
3.2.2 Alternative T1 Hydraulics

The Alternative T1 hydraulic elements are show schematically in Figure 3-5. They include the following:

- CSO-003 and CSO-004 diversions;
- Shaft 1, Shaft 2, Shaft 3, and Shaft 4;
- Relocated CSO-004 Outfall;
- Wet Weather Pump Station; and
- Interceptor Hydraulic Grade Line (HGL) Control Structure.

Storms that are completely captured by the tunnel do not overflow. These are dewatered when capacity is available at AlexRenew. Note that there is a passive gravity connection from Shaft 4 to the WWPS discharge pipe. CSO by gravity only occurs if the tunnel is full and the WWPS is down or capacity exceeded. In this rare case, the intercepting sewers entering the WRRF are surcharged with the potential for sewer backups. In this case the interceptor system would operate as it does currently, but it is expected that this would be a rare occurrence. Note that currently loss of pumping at the WRRF under very high flow conditions also results in surcharging.

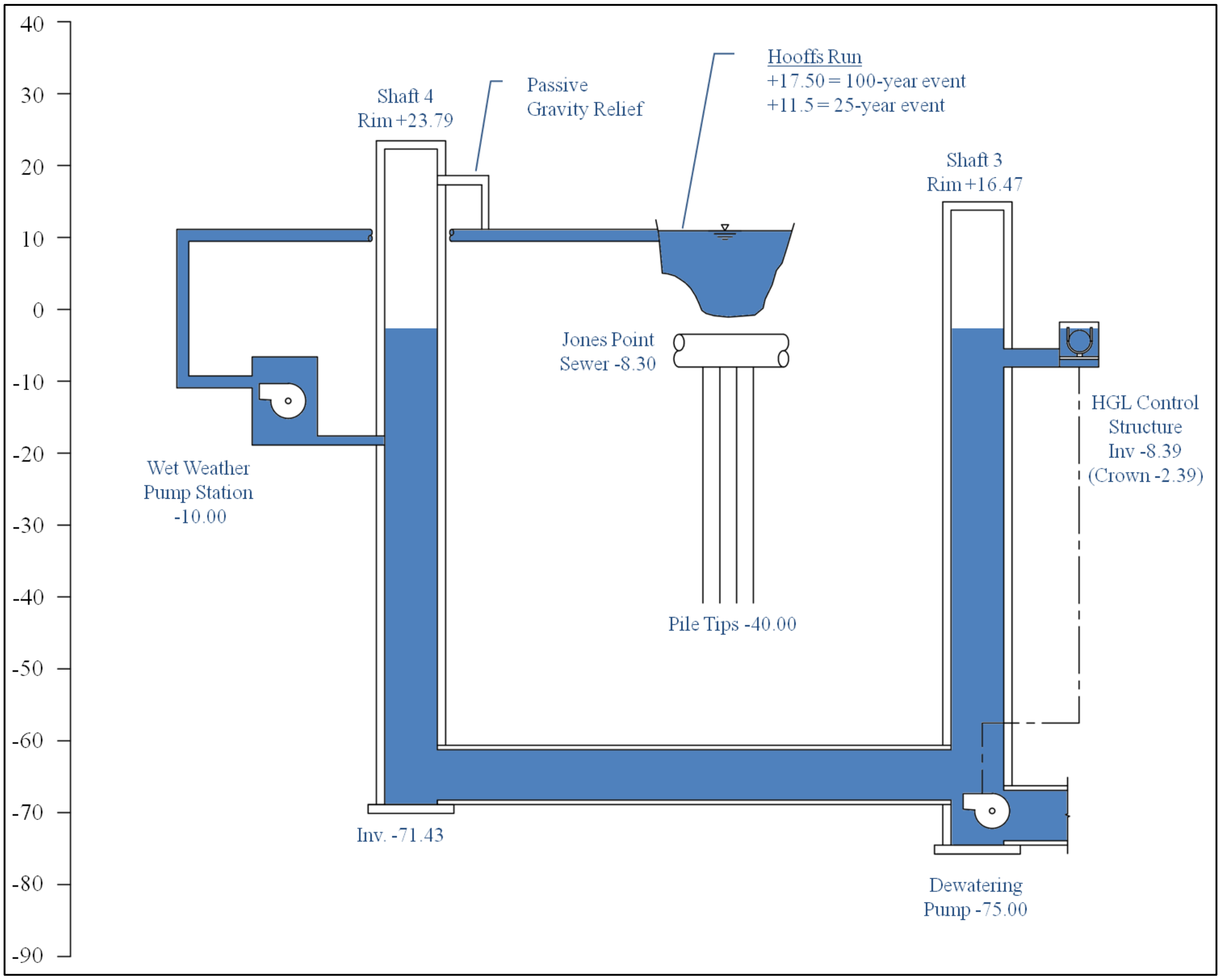
Figure 3-5
Alternative T1 Hydraulic Schematics



A more detailed hydraulic profile of Shaft 3 and Shaft 4 is shown in Figure 3-6. Elements shown in this figure include:

- Shaft 3 and Shaft 4;
- HGL Control Structure;
- Wet Weather Pump Station;
- Dewatering Pump; and
- Hooffs Run.

Figure 3-6
Alternative T1: Shaft 3 and Shaft 4 Hydraulic Profile

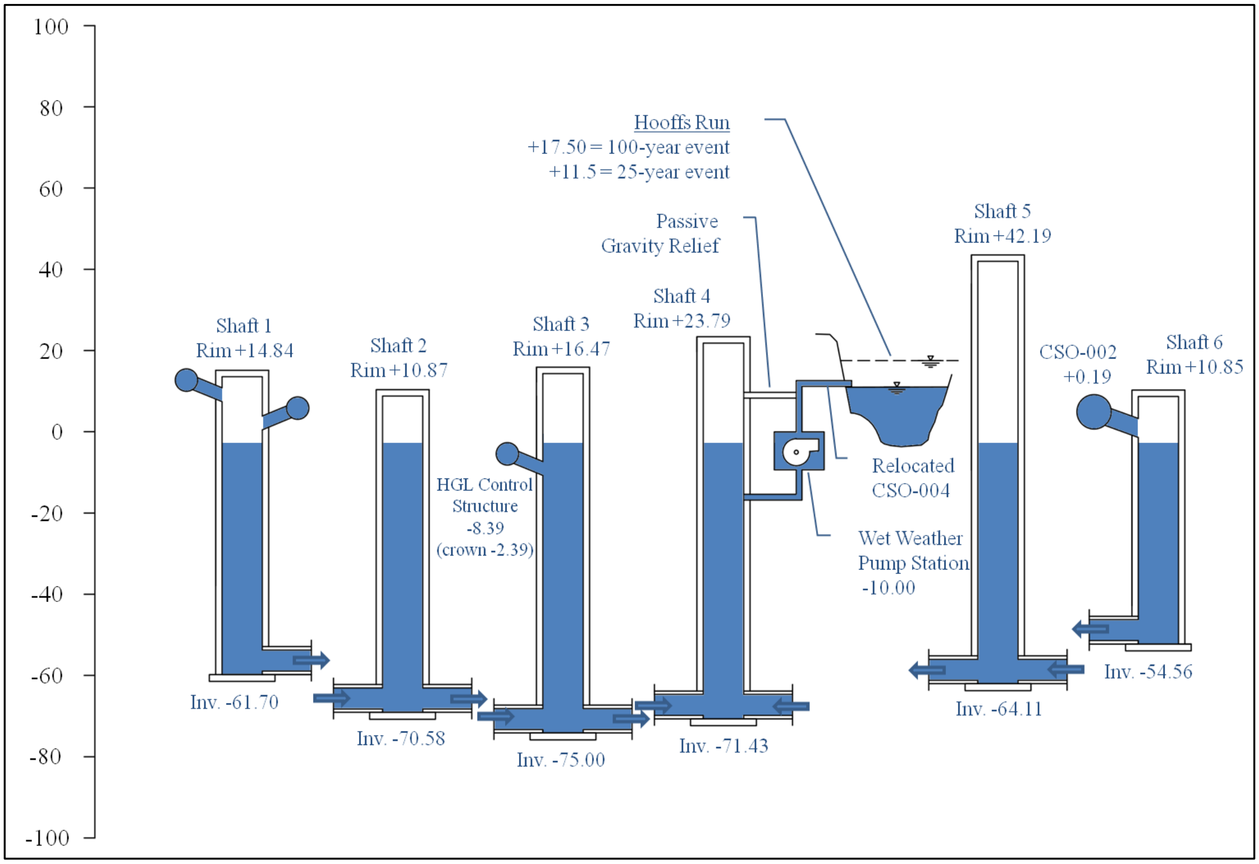


3.2.3 Alternative T2 Hydraulics

The Alternative T2 hydraulic elements are show schematically in Figure 3-7. Included are the elements listed for Alternative T1 and these additional elements:

- CSO-002 diversion; and
- Shafts 5 and Shaft 6.

Figure 3-7
Alternative T2 Hydraulic Schematics



Note Shaft 6 has a dropshaft control structure to prevent flow from the Royal Street CSS area from inundating the AlexRenew interceptor system. To prevent interceptor surcharging, an automated gate will close off flow from the Royal Street area whenever the HGL control structure shows a water elevation above its control point to prevent sewer backups.

In addition, it is important that Alternative T2 does not transfer additional overflow from the CSO 002 to the relocated outfall in Hoofs Run where the level of control needed is much higher than at Royal Street. When the WWPS engages to pump flow to the relocated outfall, the CSO-002 dropshaft control structure gate will close allowing Royal Street area flow to be discharged to the existing Royal Street outfall.

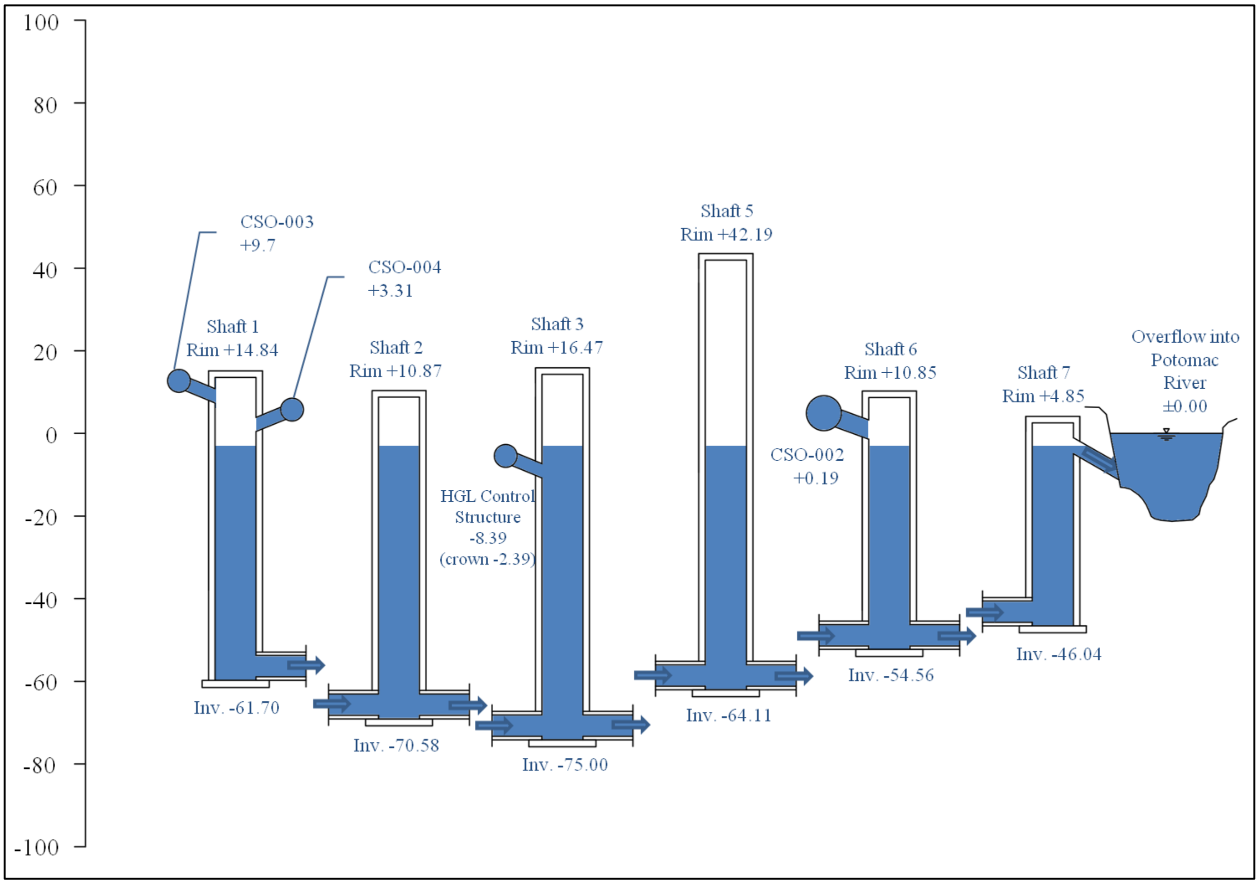
The dropshaft control structure is described in more detail in Section 3.3.5.

3.2.4 Alternative T3 Hydraulics

The Alternative T3 hydraulic elements are show schematically in Figure 3-8. Included are the elements listed for Alternative T1 and these additional elements:

- Relocated Potomac Outfall (Shaft 7);
- Shaft 1, Shaft 2, Shaft 3, Shaft 5, Shaft 6, and Shaft 7; and
- HGL Control Structure (at the WWTP)

Figure 3-8
Alternative T3 Hydraulics Schematic



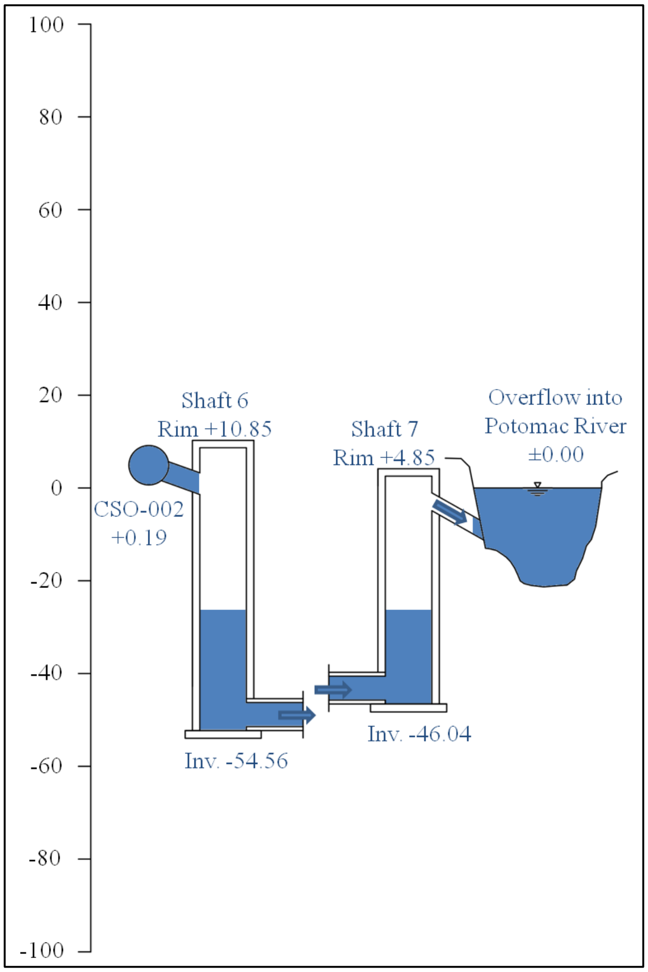
Note that the CSO-002 Drop shaft control Structure is not required for Alternative T3 since the tunnel will overflow to the Potomac River rather than Hooffs Run as in Alternative T2.

3.2.5 Alternative T4 Hydraulics

This alternative includes a tunnel capturing CSO-002 only and conveying CSO-002 flow to the Potomac River north of the Wilson Bridge. CSO-003 and 004 are addressed by other means, possibly Alternative T1. Included are these elements:

- Relocated Potomac Outfall;
- Shaft 6 and Shaft 7; and
- CSO-002 Diversion Structure.

Figure 3-9
Alternative T4 Hydraulics Schematic



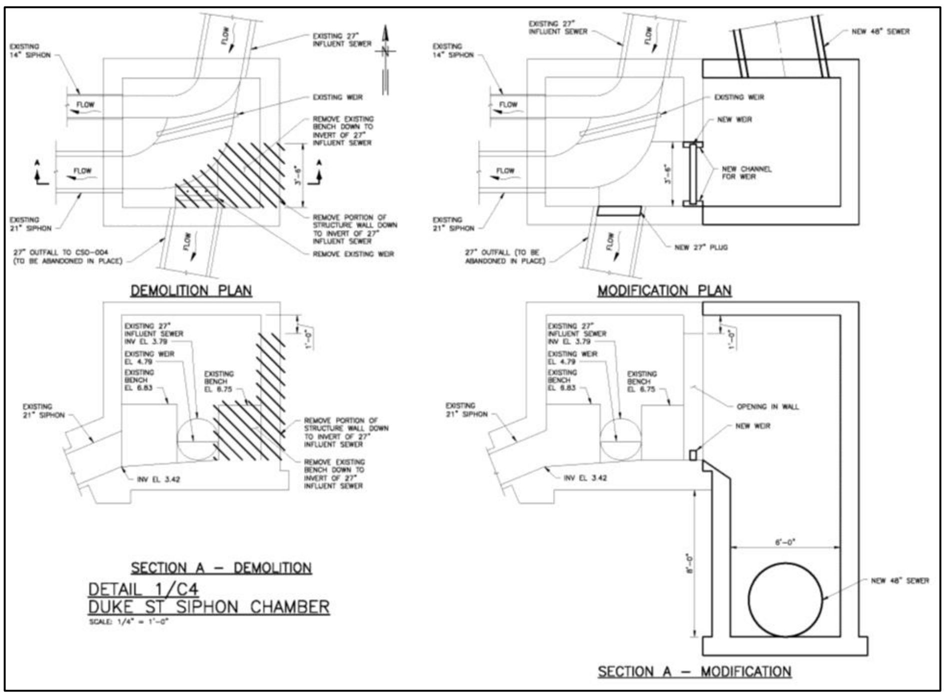
Note that the CSO-002 dropshaft control structure (described in Alternative T3) does not need the automated mechanical gate to prevent flow from being transferred to Hooffs Run.

3.3 Diversion Structures

3.3.1 CSO-004 Diversion Structure

To divert the overflow from CSO-004 into the upstream dropshaft (Shaft 1) a new diversion structure is needed. This diversion structure is designed in such a way that it functions in the same way that the current CSO-004 regulator structure functions. Existing flows to the AlexRenew WRRF continue to be conveyed to the plant, while the current overflows are diverted into the tunnel and the existing outfall pipe is blocked off and abandoned. A conceptual design for the new CSO-004 diversion structure is shown in Figure 3-10 below.

Figure 3-10
Proposed CSO-004 Diversion Structure

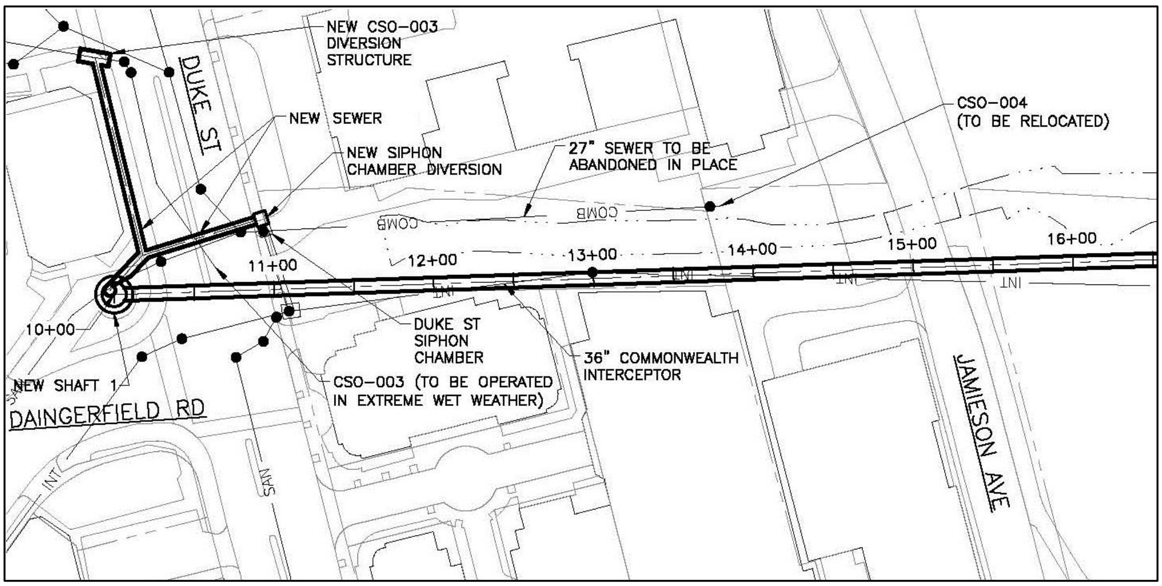


The new diversion structure at CSO-004 is required for Alternatives T1, T2, and T3. The new CSO-004 diversion structure diverts the flows back to the north side of Duke Street, to the dropshaft. An overall site plan of this diversion is shown in Figure 3-11.

3.3.2 CSO-003 Diversion Structure

The current CSO-003 outfall pipe passes right past the proposed upstream dropshaft (Shaft 1). Here flow would be typically diverted into Shaft 1 where it is stored. If the tunnel system becomes full to the point that there could potentially be basement backups, an automated gate will close causing the wet weather flow to continue out the existing CSO-003. The gate will close once the level in Shaft 3 reaches an elevation of -2.89-ft. As part of the CSO-003/004 tunnel a diversion structure is needed to divert flows from the CSO-004 outfall as described above. This diversion is required for Alternatives T1, T2, and T3. An overall site plan for this diversion is shown in Figure 3-11.

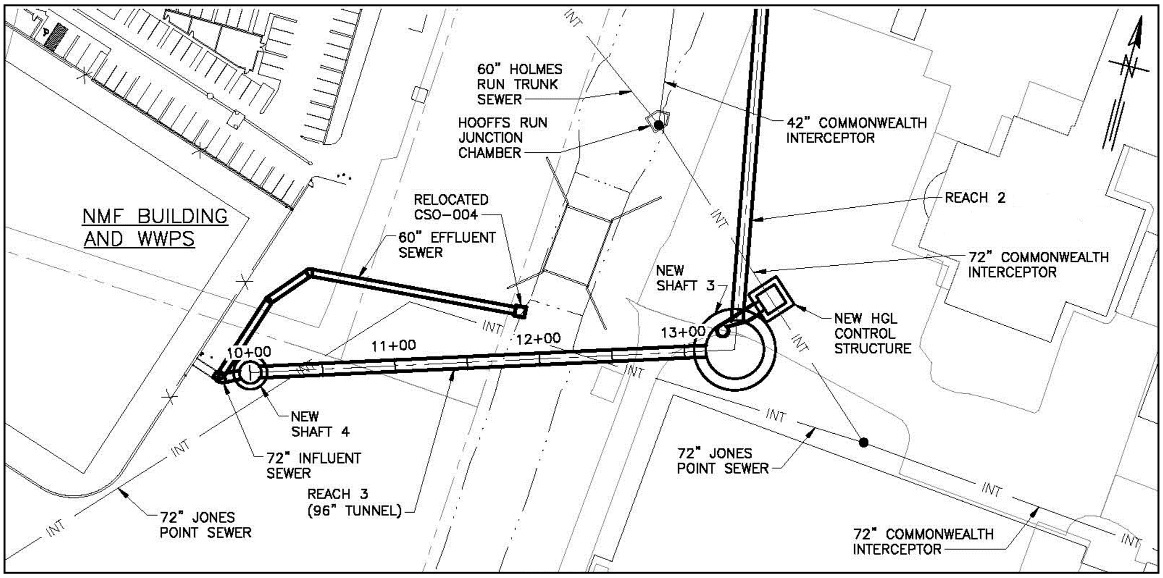
Figure 3-11
Proposed CSO-003/004 Diversion Plan View



3.3.3 Interceptor HGL Control Structure

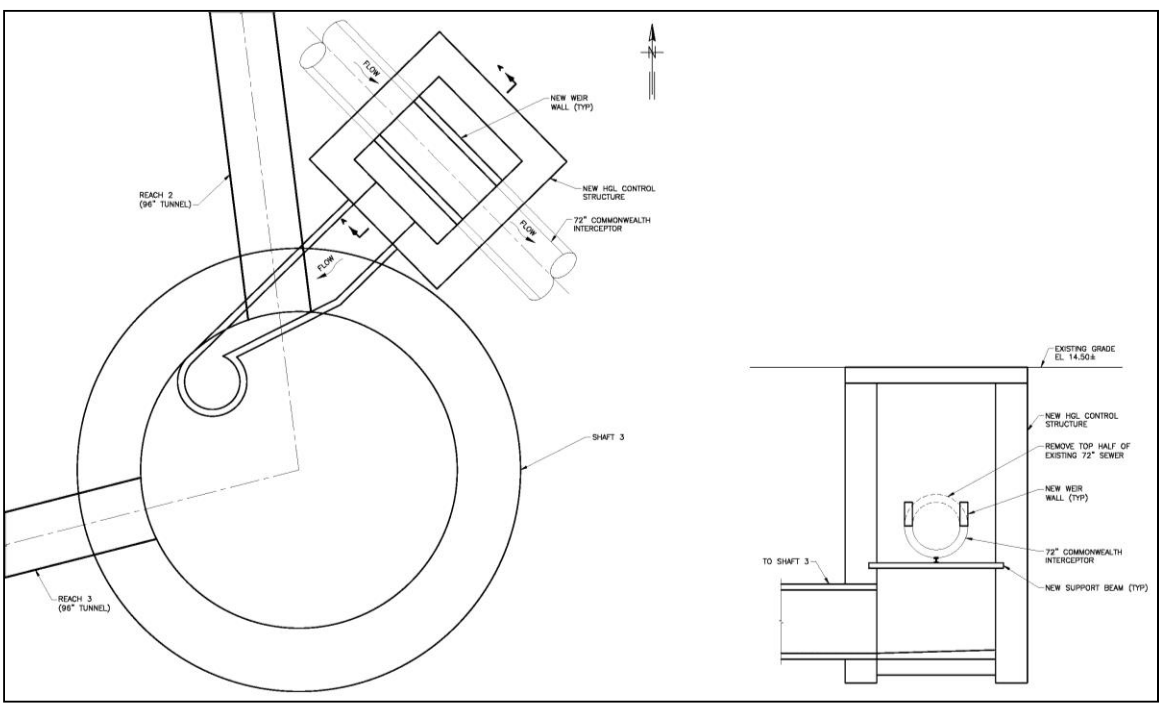
In addition to limiting CSOs, the tunnel also helps to prevent surcharging of the AlexRenew interceptor sewers. During large storm events the interceptors in the City may become surcharged, possibly leading to basement backups; this tunnel can also be used to control those backups. A new HGL control structure is located on the AlexRenew site to hold the water level in the interceptor at the crown of the pipe. Any additional flow in the interceptor with the potential to cause surcharging will be diverted into the tunnel. This HGL control structure is required for Alternatives T1, T2, and T3. An overview of the site for the HGL control structure and the preliminary location for the relocated CSO-004 is shown in Figure 3-12.

Figure 3-12
Proposed HGL Control Structure Plan View



A detail of the HGL control structure is shown below in Figure 3-13.

Figure 3-13
Proposed HGL Control Structure



3.3.4 CSO-002 Diversion Structure

The CSO-002 diversion structure is located just north of the proposed dropshaft at the intersection of Green Street and Royal Street (Shaft 6). This diversion consists of a weir that will divert flow into an existing parallel 24” sanitary sewer. When wet weather occurs, flows overtop the weir and flows into the dropshaft (Shaft 6). This diversion structure is required as part of Alternatives T2, T3, and T4. A plan view of this diversion structure is shown in Figure 3-14 and a detail of the diversion is shown in Figure 3-15.

Figure 3-14
Proposed CSO-002 Diversion Structure Plan View

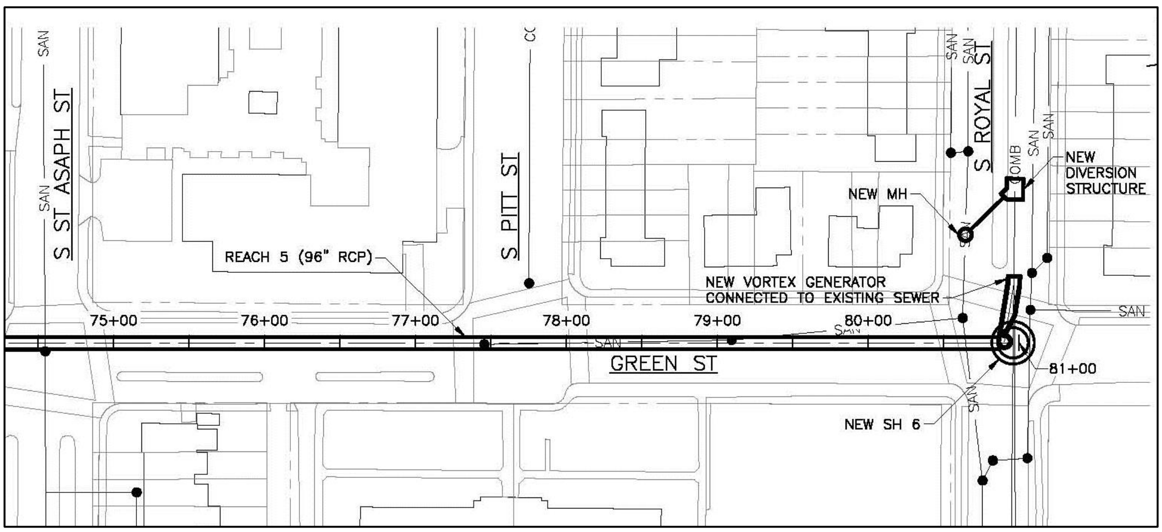
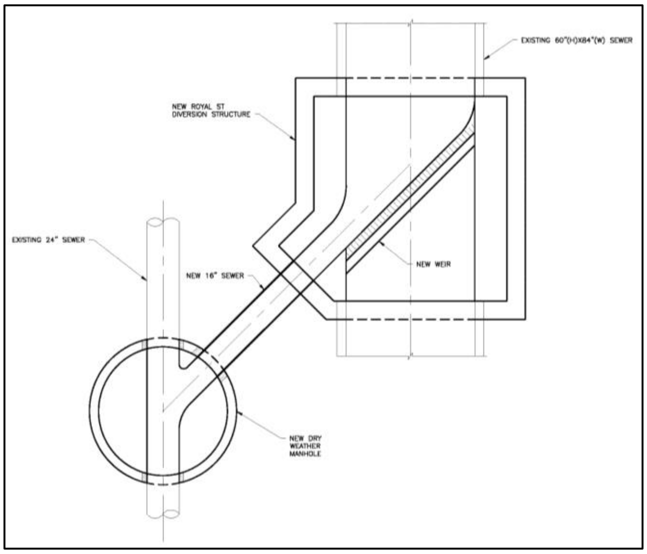


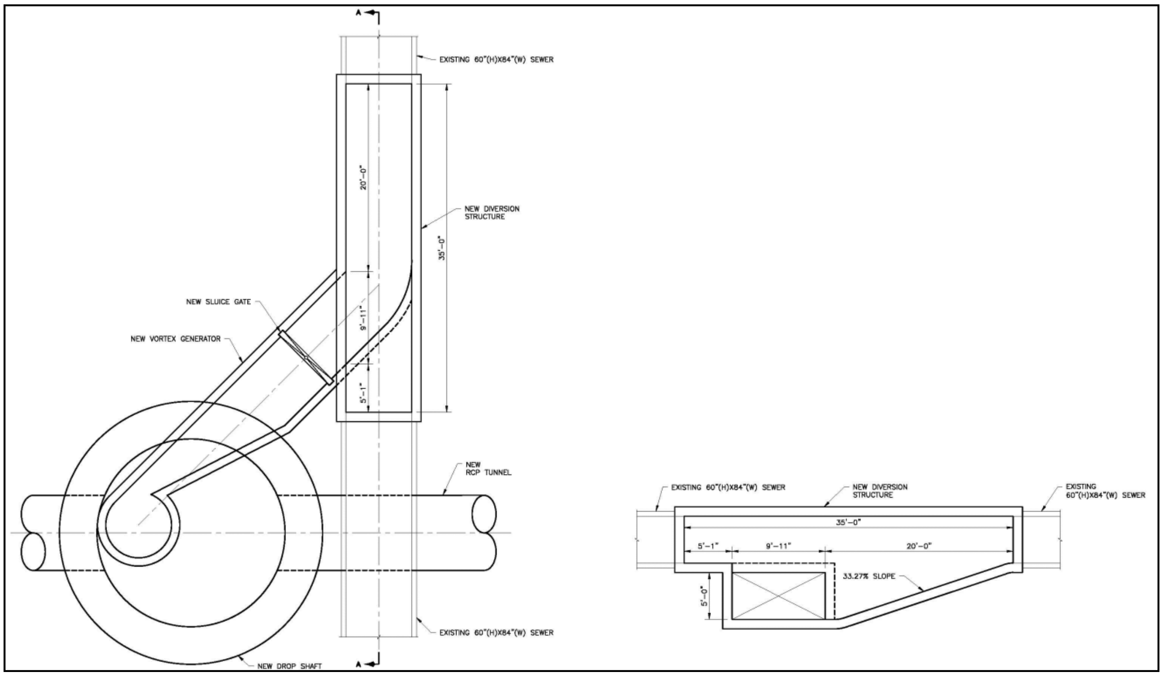
Figure 3-15
Proposed CSO-002 Diversion Structure



3.3.5 CSO-002 Dropshaft Control Structure

As described in section 3.2.3, Shaft 6 contains a dropshaft control structure in Alternatives T2 and T3. Once wet weather flow overtops the weir in the CSO-002 diversion structure it continues downstream to the new CSO-002 dropshaft control structure. Here flow is typically diverted into Shaft 6 where it is stored. If the tunnel system becomes full to the point that there could potentially be basement backups, an automated gate will close causing the wet weather flow to continue out the existing CSO-002. The gate will close once the level in Shaft 3 reaches an elevation of -2.89-ft. The same controls will be implemented at CSO-003 and Shaft 1 to prevent flows from CSO-003 causing basement backups. A detail of the CSO-002 and CSO-003 dropshaft control structure is shown in Figure 3-16.

Figure 3-16
Proposed CSO-002 Dropshaft Control Structure



3.4 Location and Layout

The proposed alignments (plan and profile) are included as attachments to this document. When constructing a tunnel it is ideal to tunnel through rock to build the tunnel. Due to local geology, rock is too deep and it is prohibitively expensive and unreasonable to construct a tunnel in rock in Alexandria. Therefore the tunnel is constructed in the Potomac Clay layer. To ensure that each of the tunnel options is constructed within the clay layer the upstream dropshaft (Shaft 1) will need to be a minimum of 75-ft deep with an invert near -62.0-ft. The upstream dropshaft for CSO-002 (Shaft 6) tunnel will need to be 65-ft deep with an invert near -55.0-ft. Assuming a 0.50% slope, the terminal dropshaft (Shaft 3) will be 90-ft deep with an invert near -75-ft. Conceptual plan and profile designs were developed for all three options and can be found as follows:

- Attachment B: CSO-003/004 Tunnel from CSO-003/004 to AlexRenew WRRF (Alternative T1)
- Attachment C: CSO-003/004 Tunnel and CSO-002 Tunnel to AlexRenew WRRF (Alternative T2)
- Attachment D: CSO-003/004 Tunnel and CSO-002 Tunnel to the Potomac River (Alternative T3)
- Attachment E: CSO-002 Tunnel to the Potomac River (Alternative T4)

Section 4 Evaluation Criteria

The tunnel alternatives are evaluated based criterion defined in the *Evaluation Criteria Technical Memorandum* and include:

- Cost
- CSO Reduction (CSO Volume)
- Effectiveness
- Implementation Effort
- Impact to the Community
- Expandability
- Net Environmental Benefit
- Nutrient Credits for the Chesapeake Bay TMDL
- Permitting Issues
- Required Maintenance

The *Alternatives Evaluation: Ranking and Recommendation Technical Memorandum* will rank the alternatives based on the above criteria and established weighting. The following sections are provided to illustrate how the individual CSO alternatives will rank.

4.1 Cost

Tunnel costs are estimated based on the costs generated for other tunnel projects in major urban areas. Much of this information is presented in the *Basis for Cost Opinions Technical Memorandum* developed as part of the Long Term Control Plan Update. Cost estimates were developed for both the A and B sizing scenarios.

4.1.1 Capital

4.1.1.1 Tunnel

Unit cost and cost curves were developed based on information collected from other tunnels throughout the country. For more information please refer to the *Basis for Cost Opinions Technical Memorandum*.

4.1.1.2 Dropshaft

As described in the *Basis for Cost Opinions Technical Memorandum*, dropshafts are required to convey flow into the tunnel. A dropshaft is made up of three parts:

- Tangential inlets;
- Vertical dropshaft; and
- Deaeration chamber.

Each of these components has a separate cost curve and is used in calculating the overall construction cost of the dropshaft. The cost curves are based on work done as part of the DC Water Long Term Control Plan, and updated for the City's LTCPU.

4.1.1.3 Screening Facility

A screening facility is required anywhere pumping takes place in the tunnel system. A screening allowance is included.

4.1.1.4 Dewatering Pump Station

A dewatering pump station is required at the lowest point in the tunnel system in order to pump out the tunnel when the AlexRenew WRRF is able to accept flow. For the alternatives described previously only one dewatering pump station is required. Costs are estimated based on flowrate.

4.1.1.5 HGL Control Structure and Wet Weather Pump Station (WWPS)

As described in previous sections, the HGL control structure and wet weather pump station are needed to alleviate the possibility of basement backups in the City of Alexandria during very large wet weather events. Based on work done as part of the wet weather improvements planning efforts by the City, Fairfax County, and AlexRenew, it is estimated that the new HGL control structure and wet weather pump station cost approximately $7,100,000.

4.1.1.6 Project Costs

Project costs include planning, design, construction management, administration, permitting, and easements. The project costs are estimated at 35% of the overall construction cost.

4.1.1.7 Land Acquisition

The proposed alignments have been created to minimize impact to the community and consequently require minimal easements or land acquisition. It will be necessary to acquire access to some land owned by others and an estimate has been made in order to generate cost estimates.

4.1.1.8 Overall Capital Cost for Each Alternative

The table below presents the estimated cost for each tunnel alternative and each scenario. These costs include all of the items mentioned above, a 35% construction contingency, a 35% project cost, and estimated costs of land acquisition. Line item costs for each of the estimates in the table below are presented in Attachment F.

Alternative	Scenario	Outfall Captured	Construction Cost	Project Costs	Land Acquisition	Estimated Capital Cost
T1[1]	A	CSO-003/004	$44.0	$15.4	$1.1	$60.5
	B	CSO-003/004	$108.9	$38.1	$1.1	$148.1
T2[1]	A	CSO-002/003/004	$78.2	$27.4	$1.1	$106.6
	B	CSO-002/003/004	$224.9	$78.7	$1.1	$304.7
T3[1]	A	CSO-002/003/004	$84.7	$29.6	$3.3	$117.6
	B	CSO-002/003/004	$255.4	$89.4	$3.3	$348.0
T4	A	CSO-002	$24.6	$8.6	$1.6	$34.8
	B	CSO-002	$87.4	$30.6	$1.6	$119.7

[1] Select wet weather improvements, including hydraulic grade line control structure, AlexRenew WRRF upgrades and the wet weather pump station, will be shared facilities with Fairfax County. The cost split for these shared facilities will be determined at a later date.

4.2 CSO Reduction (CSO Volume)

Utilizing XPSWMM hydraulic modeling software, the CSO volume reduction has been estimated and ratings have been assigned to each alternative.

Alt.	Scenario	Current CSO Volume (MG)	Proposed CSO Volume (MG)	CSO Stored and Treated (MG)	Comparison Year	% Reduction	% Capture	Rating
T1	A	17.89	2.60	15.29	1984	85.5%	96.9%	High
	B	67.82	0.02	67.80	2004-2005	99.9%	99.9%	Very High
T2	A	60.80	8.71	52.09	1984	85.7%	95.4%	High
	B	186.98	4.85	182.13	2004-2005	97.4%	98.7%	Very High
T3	A	60.80	8.71	52.09	1984	85.7%	95.4%	High
	B	186.98	4.85	182.13	2004-2005	97.4%	98.7%	Very High
T4	A	42.91	6.11	36.80	1984	85.8%	94.2%	High
	B	119.16	5.67	113.49	2004-2005	95.2%	97.0%	Very High

4.3 Effectiveness

The effectiveness is based on how well each alternative reduces the bacterial input to the receiving waters. The effectiveness of each alternative is based on the CSO volume reduction and discharge location. Alternatives T3 and T4 relocate the outfall to the Potomac River, so there is a 100% bacteria reduction from CSO's in Hooffs Run and Hunting Creek.

Alternative	Scenario	Comparison Year	% Reduction in Hunting Creek	Rating
T1	A	1984	85.5%	High
	B	2005	99.9%	Very High
T2	A	1984	85.7%	High
	B	2005	97.4%	Very High
T3	A	1984	100%	Very High
	B	2005	100%	Very High
T4	A	1984	100%	Very High
	B	2005	100%	Very High

4.4 Implementation Effort

The implementation criterion is the feasibility and effectiveness with which all the projects in a CSO control alternative can be successfully completed. Implementation factors are presented in the form of questions in the table below.

Alternative	Scenario	Are construction projects low in complexity or have commonly implemented technologies?	Is land available in the proposed project areas?	Are there adequate amounts of resources, labor, and expertise to complete projects?	Can the proposed project(s) be reasonably constructed in the highly urban environment?	Is it likely the LTCPU deadlines will be met?	Rating
T1	A	No	Yes	Yes	Yes	Yes	High
	B	No	No	Yes	No	Yes	Low
T2	A	No	Yes	Yes	Yes	Yes	High
	B	No	No	Yes	No	Yes	Low
T3	A	No	Yes	Yes	Yes	Yes	High
	B	No	No	Yes	No	Yes	Low
T4	A	No	Yes	Yes	Yes	Yes	High
	B	No	No	Yes	No	Yes	Low

The Scenario B alternatives require more land for construction of the dropshafts and the laydown space needed during construction. There is insufficient land for many of the potential sites for the larger dropshafts needed during construction; therefore the Scenario B alternatives receive an answer of "No" for this question. Due to these land requirements it is not reasonable to conclude that the Scenario B alternatives can be constructed in the highly urban environment of the City of Alexandria.

4.5 Impact to the Community

For each of the alternatives, the main impact to the community will be the location of each of the dropshafts and the construction associated with each one. Much of the construction will be located at dropshafts on the AlexRenew plant site however some of the other dropshafts will require construction on private property and National Park Service property.

Alternative	Scenario	Description	Rating
T1	A	A small dropshaft is located on private property at the north end of the tunnel. One dropshaft is located in a City park. The rest of the dropshafts are located on the AlexRenew site.	High
	B	A large dropshaft is located on private property at the north end of the tunnel. One dropshaft is located in a City park. The rest of the dropshafts are located on the AlexRenew site.	Medium
T2	A	A small dropshaft is located on private property at the north end of the tunnel. One dropshaft is located in a City park. The rest of the dropshafts are located on the AlexRenew site or within the City right-of-way.	High
	B	A large dropshaft is located on private property at the north end of the tunnel. One dropshaft is located in a City park. The rest of the dropshafts are located on the AlexRenew site or within the City right-of-way.	Medium
T3	A	A small dropshaft is located on private property at the north end of the tunnel. Another small dropshaft is located on National Park Service land. One dropshaft is located in a City park. The rest of the dropshafts are located on the AlexRenew site or within the City right-of-way.	Low
	B	A small dropshaft is located on private property at the north end of the tunnel. Another small dropshaft is located on National Park Service land. One dropshaft is located in a City park. The rest of the dropshafts are located on the AlexRenew site or within the City right-of-way.	Low
T4	A	A small dropshaft is located on National Park Service land. The other dropshaft is located within the City right-of-way.	Medium
	B	A large dropshaft is located on National Park Service land. The other dropshaft is located within the City right-of-way.	Medium

4.6 Expandability

Each of the tunnel alternatives can be constructed in phases or even expanded (i.e. lengthened) to capture additional CSO volume. Acquiring easements and land for dropshaft construction could be the most challenging part of expanding the tunnel system in the future.

Alternative	Scenario	Rating
T1	A	High
	B	Medium
T2	A	High
	B	Medium
T3	A	High
	B	Medium
T4	A	High
	B	Medium

4.7 Net Environmental Benefit

The net environmental benefit is based on each alternative's Envision base score. More information about this ranking can be found in the *Evaluation Criteria Technical Memorandum*.

Alternative	Scenario	Very High Base score + >35	High Base score + 26-35	Medium Base score + 16-25	Low Base score + 6-15	Minimal Base score + 0-5
T1	A			X		
T2	A			X		
T3	A			X		
T4	A			X		

Alternative	Scenario	Very High Base score + >35	High Base score + 26-35	Medium Base score + 16-25	Low Base score + 6-15	Minimal Base score + 0-5
T1	B			X		
T2	B			X		
T3	B			X		
T4	B			X		

4.8 Nutrient Credits for the Chesapeake Bay TMDL

Each of these alternatives will store and treat CSO flow. A majority of the flow is stormwater which will require reductions of loads under the Chesapeake Bay TMDL. By capturing and treating this stormwater, nutrients credits can be generated for stormwater that could possibly be applied elsewhere throughout the City.

Alternative	Scenario	Total Suspended Solids (lbs/yr)	Total Nitrogen (lbs/yr)	Total Phosphorous (lbs/yr)	N/P/TSS NPW ($ in millions)	Rating
T1	A	8,219	367	76	($2.2)	Minimal
	B	25,231	1,127	235	($6.8)	Medium
T2	A	27,999	1,250	260	($7.5)	Medium
	B	67,500	3,014	628	($18.1)	Very High
T3	A	27,999	1,250	260	($7.5)	Medium
	B	67,500	3,014	628	($18.1)	Very High
T4	A	19,780	883	184	($5.3)	Low
	B	42,270	1,887	393	($11.3)	High

A 20-year net present worth cost avoidance is estimated for each parameter (N/P/TSS) based on planning level unit costs for removing the parameter through a new stormwater BMP. Planning level unit costs vary widely and are highly site specific; however, for the purposes of this evaluation the unit costs of $6,000/lb for nitrogen, $25,000/lb for phosphorous, and $80/lb for TSS are assumed based on the range of costs provided in the *Cost Effectiveness Study of Urban Stormwater BMPs in the James River Basin* (2013) completed by the Center for Watershed Protection. The parameter with the highest NPW cost is assumed to be the controlling parameter.

4.9 Permitting Issues

All of the tunnel alternatives will still have relief points where CSO's will still occur when the tunnel system becomes overwhelmed during very large wet weather events. This will require modifications to the existing CSO permit in order to accommodate these major changes to the system. Additionally Alternatives T3 and T4 will require working with the National Park Service (NPS) to accommodate dropshaft construction and outfall relocation. It is anticipated that negotiations and permitting with NPS will be difficult and time consuming.

Alternative	Scenario	Rating
T1	A	Medium
	B	Medium
T2	A	Medium
	B	Medium
T3	A	Low
	B	Low
T4	A	Low
	B	Low

4.10 Required Maintenance

There will be new maintenance procedures to keep the tunnel systems functioning properly. Some of the maintenance activities could include: quarterly inspection and cleaning of the tunnels, regular inspection and maintenance of the screening facilities, regular inspection and maintenance of the dewatering pump station, and regular inspection and maintenance of the wet weather pump station. Due to the length and complexity of the tunnel alternatives, maintenance will take longer and cost more for some of the alternatives as opposed to others.

Alternative	Scenario	Rating
T1	A	Medium
	B	Medium
T2	A	Medium
	B	Medium
T3	A	Medium
	B	Medium
T4	A	Medium
	B	Medium

4.10.1 O&M Costs

Annual operation and maintenance (O&M) costs are also estimated for the tunnel alternatives and scenarios.

Alternative	Scenario	Outfall Captured	Annual O&M
T1	A	CSO-003/004	$0.6
	B	CSO-003/004	$1.5
T2	A	CSO-002/003/004	$1.2
	B	CSO-002/003/004	$3.2
T3	A	CSO-002/003/004	$1.2
	B	CSO-002/003/004	$3.5
T4	A	CSO-002	$0.5
	B	CSO-002	$1.4

4.11 Net Present Worth

The net present worth (NPW) is estimated based on a twenty (20) year period and a 3.0% discount rate. The NPW includes capital costs, annual O&M, and cost avoidance for constructing new stormwater BMPs.

Alternative	Scenario	Outfall Captured	Estimated Capital Costs	O&M NPW	N/P/TSS NPW	NPW
T1[1]	A	CSO-003/004	$60.5	$8.5	($2.2)	$66.8
	B	CSO-003/004	$148.1	$21.6	($6.8)	$162.9
T2[1]	A	CSO-002/003/004	$106.6	$17.6	($7.5)	$116.7
	B	CSO-002/003/004	$304.7	$47.5	($18.1)	$334.1
T3[1]	A	CSO-002/003/004	$117.6	$18.5	($7.5)	$128.6
	B	CSO-002/003/004	$348.0	$52.1	($18.1)	$382.0
T4	A	CSO-002	$34.8	$7.7	($5.3)	$37.2
	B	CSO-002	$119.7	$21.7	($11.3)	$130.0

[1] Select wet weather improvements will be shared facilities with Fairfax County. The cost split for these shared facilities will be determined at a later date.

4.12 Recommendation for Alternative Scoring

It is recommended that all of the Scenario A tunnel alternatives be moved forward for scoring and ranking relative to the other alternatives.

The Scenario B tunnel alternatives are unfavorable and impractical due to the very large volume requirements, insufficient land availability, and extraordinarily high capital costs. It is recommended Scenario B tunnel alternatives be eliminated from further consideration.

Section 5 Opportunities for Synergy with Other Technologies

The tunnel alternatives are considered primary control strategies. Within individual basins, there are limited opportunities for synergy with other primary technologies (i.e. storage tanks, disinfection, etc.). Once constructed the tunnel alternatives lend themselves well to complementary technologies including progressive separation and green infrastructure.

On an inter-basin level, the use of tunnels does not preclude the use of other primary control strategies in other basins. For example, a storage tunnel could be used for CSO 003/004, while a storage tank could be installed for CSO 002.

Section 6 Additional Investigation Needs (if alternative retained)

If the storage alternatives are retained the following additional investigations should be considered:

- Detailed site selection study for the dropshafts;
- Detailed tunnel alignment study;
- Detailed sizing study;
- Geotechnical borings and study, including geological stream beds/historical stream valley delineation; and
- Surge Analysis.

Attachment A

Tunneling Technologies

JACOBS ASSOCIATES

Engineers/Consultants

PROJECT TECHNICAL MEMORANDUM

To:	John McGettigan – Greeley and Hansen
cc:	
From:	Tennyson Muindi and Daniel Dobbels
Job No.:	5245.0 – CSS Long Term Control Plan Update, Alexandria, VA
Date:	30 March, 2015
Subject:	Conceptual Tunneling Alternatives Evaluation

1 Memorandum Scope

This memorandum presents conceptual engineering design and constructability evaluations for the construction of new Combined Sewer Systems (CSS) tunnels in Alexandria, Virginia, and was prepared in support of the Infrastructure Alternatives being developed by Greeley and Hansen for the City of Alexandria. It also includes an underground storage tank evaluation in the proximity of Outfall 002. This work was performed as authorized by Task Order No: 13-02 in the services agreement between Greeley and Hansen and Jacobs Associates dated July 31, 2014.

2 Project Description

The proposed CSS tunnel alternatives under evaluation are located in the southeastern area of Alexandria, north of Interstate 495 (I-495) and west of the Potomac River as shown on the aerial photo, Figure 1. The selected alternative will be advanced to preliminary and final design. A general description of the concept layouts follows.

One alignment runs north to south along Hooffs Run from Drop Shaft-1 (DS-1) near the intersection of Duke Street and Dangerfield Road to DS-3 near the AlexRenewNMF. This alignment is about 2,600 LF long and has an average slope of approximately 0.5%. Tunnel invert depths based on a 96-inch diameter alternative range from about 75 feet to 100 feet below ground surface at DS-1 and DS-3, respectively.

The second alignment alternative runs east to west and north/parallel to I-495 from DS-7 near the Potomac River to DS-3. This alignment is about 6,130 LF long and has an average slope of approximately 0.5%. Tunnel invert depths based on a 96-inch diameter alternative range from about 50 feet to 100 feet below ground surface at DS-7 and DS-3, respectively.

An additional tunnel alternative crosses Hooffs Run from DS-4 and ties into DS-3. This alignment is about 300 LF long and has an average slope of approximately 1.0%. The depths to tunnel invert based on a 96-inch diameter alternative range from about 37 feet to 50 feet below ground surface at DS-4 and DS-3, respectively.

Three additional tunnel size alternatives with diameters of 72-inches, 120-inches and 144-inches are also being considered. All three would be located along the same alignment and have similar configuration as the 96-inch diameter tunnel noted above.

3 Information Reviewed

Greeley and Hansen provided the following project information for review:

- Tunnel Configuration Alternative – Plan and Profile: City of Alexandria, LTCP Update, dated November 2014
- Boring information from three developments in the vicinity of Duke Street (DS-1).
- Boring information from memo by CH2M Hill in the vicinity of DS-3.
- VDOT test boring information at Washington Street

Additionally, we have considered published regional geologic information.

4 Subsurface Site Conditions

4.1 Regional Geology Profile

Physiographically, the project area is defined by the United States Geological Survey (USGS) as the Atlantic Coastal Plain (ACP) Province. This province extends eastward from the northeast to southwest trending “fall line” (the boundary defined by the hard bedrock of the Piedmont Province to the west and the softer low-lying sediments of the ACP Province) eastward to the Atlantic Ocean.

The ACP sediments date back to Cretaceous Age deposits overlain by Cenozoic Era deposits overlain in-turn by Pleistocene terrace deposits, recent alluviums and man-made fills. The Cretaceous soils, referred to locally as the Potomac Group, consist primarily of hard over-consolidated clays and some very dense granular materials. The Potomac Group is further divided into the upper Patapsco/Arundel high and low plasticity clays/silts and the more granular underlying Patuxent soils.

Above the Potomac Group are the Cenozoic terrace deposits that are generally loose to dense granular materials at greater depth and soft to medium stiff clays or silts at shallower depths. The recent alluvial soils related to meandering river channels, form the upper layer(s) of naturally occurring sediments. These materials can be granular or fine-grained and even include occasional organic materials. Man-made fills are also common throughout the southeastern area of Alexandria with depths of up to 30 ft. not being uncommon. In general, the depth of fill decreases from west to east approaching the Potomac River.

4.2 Anticipated Subsurface Conditions

Subsurface conditions are in general anticipated to be similar to those discussed in the regional geology profile above. Based on the very limited available data in the vicinity of proposed alignments, the following soil strata sequence was noted: Fill, Alluvium, Terrace and Potomac deposits. The limited information was mainly from three localized areas which include: a) existing buildings on Duke Street (near DS-1), b) the AlexRenewNMF (near DS-3) and c) VDOT test borings on Washington Street (south of alignment between DS-5 and DS-6).

For planning purposes, it can be assumed that the four soil strata will most likely be encountered at all drop shaft locations. Based on the conceptual invert depths of the tunnel, it is anticipated that the tunnel horizon will be located primarily in the stiff to hard clay of the Potomac deposit (favorable for tunneling). A detailed evaluation should be conducted along the selected alignment to better define the subsurface conditions including the top of the Potomac clay.

4.3 Anticipated Groundwater Levels

It is anticipated that groundwater levels along the tunnel alignments will vary. Based on review of data in the three localized areas noted in the previous section, groundwater was encountered in the Fill and Alluvium deposits. The information near Duke Street notes tendency for perched water tables.

Hooffs Run flows southerly over the tunnel alignment from Duke Street (near DS-1) and connects to Hunting Creek just south of I-495. The west to east tunnel alignment terminates at the Potomac River. It should be noted that groundwater levels are expected to fluctuate with precipitation, season, temperature, or from construction activities in the vicinity. Both Hooffs Run and Potomac River are prone to fluctuation causing groundwater level along the alignments to rise.

5 Alignment and Profile Considerations

Below are some conceptual tunnel layout considerations:

<u>Horizontal Alignment</u>

a. Maintain the alignment within public right-of-ways.
b. Avoid alignments that are below existing buildings.
c. Avoid alignments that parallel and are directly below existing major pipelines. If alignments that are parallel to existing major pipelines cannot be avoided, maintain an offset of at least two tunnel diameters between the tunnel and the pipeline.
d. Avoid curves if pipe jacking or microtunnel tunneling techniques are employed. While there is some precedence for pipe jacking curved alignments the technology involved is quite new to the industry and risks associated with curved pipe jacking are relatively high.

e. A minimum radius of curvature of 1000 feet is recommended if utility tunneling methods are used.

Vertical Alignment

a. Based on anticipated geologic conditions, the most favorable soil unit for tunneling is the Potomac clay. Tunneling in the Alluvium and Terrace deposits is feasible but will be more costly and have higher risks than tunneling in the Potomac clays. Accordingly, the vertical alignment of the proposed tunnels should be maintained within the Potomac clays to the extent possible.
b. A minimum separation of at least two diameters should be maintained between existing pipelines, culverts or tunnels. This separation would also apply to the bottom of piles if these conduits are supported on deep foundations.

6 Tunnel Construction Methods

The following tunneling methods were evaluated and considered for their technical feasibility on this project:

- Conventional pipe jacking
- Pipe jacking by tunnel boring machine (TBM), earth pressure balance machine (EPBM), or microtunnel boring machine (MTBM)
- Utility Tunneling with one or two-pass lining system

The following paragraphs describe the general procedure of each tunneling method, applicable tunnel methods and staging considerations.

6.1 Conventional Pipe Jacking

Pipe jacking entails the jacking of a shield (open steel cylinder located at the front of the pipe string) into an underground excavation and followed by a continuous string of pipe. The excavation is made from within the shield. The term “conventional” is used for excavations made by personnel at the face of the jacking shield using hand operated tools such as spades and shovels, or with mechanical digging arms, etc. The excavated material (spoils or muck) is typically loaded into muck carts and removed from the tunnel. Use of conventional pipe jacking is typically limited to lengths less than about 500 feet.

Control of line and grade is maintained by the use of an optical or laser guidance system and shield jacks for steering corrections.

The jacked pipe can either be a temporary casing or the product pipe. If the product pipe is jacked directly, it needs to be designed to handle the pipe jacking loads without damage. Directly jacking the product pipe is usually more economical than jacking a temporary casing pipe and installing the product pipe later due to the larger excavation size and annular backfill grouting requirement.

The friction force between the ground and the shield and pipe can be reduced by the injection of bentonite, or other lubricating fluid, into the annular space between the jacking pipe and the ground. If the shield and pipe annulus is sealed, the friction force can be reduced further by pressurizing the bentonite in the annulus to reduce the amount of closure due to unstable soils.

Face stabilization is used to minimize flowing ground behavior encountered below the groundwater table and raveling ground behavior above the groundwater table. Face stabilization for conventional pipe jacking typically consist of direct support of the face with breasting boards, doors, or sand shelves when needed. Obstructions are readily accessible due to the openness of the shield and mobility of the excavation tools.

6.2 Pipe Jacking by TBM or MTBM

A Tunnel Boring Machine (TBM), or a Microtunnel Boring Machine(MTBM - microtunneling) can perform full face bore excavations by means of a rotating circular cutterhead that is equipped with picks and/or disks that are dragged across the entire excavation face. The primary difference between a TBM and a MTBM is that a MTBM is operated remotely from the outside of the bore and typically does not have any face access because it has a pressurized face. Otherwise a MTBM can have many of the same features as a TBM or EPBM. These mechanized, full face methods of excavation typically achieve higher advance rates and can be used in a much wider range of ground conditions compared to conventional pipe jacking excavation methods. TBMs and MTBM systems typically have high mobilization costs, high capital costs, and require trained operators. Pipe jacking by TBM or MTBM is typically used for lengths greater than about 500 feet or where ground conditions make conventional pipe jacking in-feasible

The TBM or MTBM is advanced using and followed by a continuous string of pipe that supports the ground. Openings in the cutterhead permit the passing of spoils into the bore for removal. Depending on the type of boring machine deployed, spoils are removed from the face either by an auger, conveyor, or through slurry lines. Face stability is achieved in a number of different ways depending on machine style, design, and operation of the boring machine.

TBM’s that can be operated in a closed (pressurized) mode typically have a chamber behind the cutterhead which is pressurized, either with slurry (Slurry TBM) or by the use of pressurized spoils (Earth Pressure Balance TBM, EPBTBM) to balance the groundwater and earth at the face. For EPBTBMs, the pressure is controlled by the rate of spoils removal by a screw conveyor. By definition, MTBM’s are also operated in pressurized mode.

A TBM operated in an “open” mode has less precise means for stabilizing the face. Open mode TBMs can offer some stabilization by the direct pressure of the cutterhead against the soil and by reducing the size and number of cutterhead openings if needed. Face stability issues for this project will need to be evaluated to ascertain if an open mode boring machine could be considered in addition to more sophisticated pressurized face TBMs.

Removal of obstructions from the face can be challenging for a TBM and impractical for a pressurized face TBM, due to the reduced access to the face. In some cases obstructions can be cleared by backing the machine away from the face to gain adequate access. Disengaging the face may lead to soil instability and eventually surface subsidence. The obstruction is removed by manually breaking or cutting it into pieces small enough to pass through the cutter head openings.

6.3 Utility Tunneling

Utility tunneling (UT) is similar to conventional pipe jacking discussed above with the primary difference being the tunnel lining techniques. In all pipe jacking methods the jacked pipe supports the ground during the excavation. In UT, ground supports consisting of prefabricated steel or concrete liner plates, or steel ribs and wood lagging systems are installed incrementally as the excavation advances. The lining is installed in the tunneling shield or TBM near the tunnel face as the soil is removed and the tunneling shield or TBM advances and forms a continuous support of the exposed soil.

There are two basic lining system used for UT: two-pass and one-pass. A two-pass lining system is one in which an initial lining is placed as the tunnel is excavated and the final lining is placed later, typically after tunnel excavation is completed. For the ground conditions anticipated for this project, the most likely initial lining type would be steel ribs and lagging or steel liner plate. The final tunnel lining could consist of reinforced concrete pipe (RCP), centrifugally cast fiberglass reinforced polymer mortar (HOBAS) pipe, precast concrete cylinder pipe (PCCP) or cast-in-place concrete. A one-pass lining system is one in which the permanent lining is installed as the tunnel is excavated. The permanent lining typically consists of bolted and gasketed pre-cast concrete segments that are erected to form a ring within the tunneling shield or TBM. Use of one-pass lining systems is typically limited to tunnels 8 to 10 feet in diameter or larger.

The line and grade guidance systems are similar to those of conventional pipe jacking. Steering control is accomplished during the soil excavation and shield advancing process. The tunneling shield is usually equipped with jacking cylinders at its rear portion, which propel the shield forward by jacking against the already erected liner sections as the face excavation proceeds. These jacking cylinders can apply different forces and extend at different speeds during one forward tunneling cycle to correct the direction of the shield. After the shield has advanced, the jacks are retracted to leave room at the rear of the shield for the in situ installation of the new liner system. Since the liner plates are installed without being thrust into place, skin friction is considered to be negligible. This feature keeps the thrusting force fairly constant throughout the bore.

6.4 Applicable Tunneling Methods

Based on the nature of the anticipated ground conditions (primarily Potomac Group Soils) at the tunnel horizon, the tunnel construction methods provided in Table 1 are considered technically feasible. Table 1 also includes the best suited tunneling methods for the various tunnel diameters currently under consideration.

Table 1. Applicable Tunneling Methods

Method	**Diameter (feet)**			
	6	8	10	12
Pipe Jacking/Microtunneling	Yes	Yes	No	No
Utility Tunneling – one pass	No	No	Yes	Yes
Utility Tunneling – two pass	Yes	Yes	Yes	Yes

Notes:

1. Pipe jacking and microtunneling are best suited for 6-ft and 8-ft diameter sizes.
2. Utility tunneling
   a. One pass is best suited for diameters 10-ft or greater.
   b. Two pass is best suited for diameters less than 10-ft.
   c. Within the Potomac Soil group, an open face TBM can be utilized depending on the encountered soil conditions. Few sand lenses maybe manageable. Initial lining can include steel ribs and lagging or steel liner plates.
   d. Numerous sand lenses can be problematic if encountered within the Potomac Soil group and would require use of an Earth Pressure Balance TBM. Gasketed liner plate can be used with pipe grouted in place.
   e. If Alluvial or Terrace deposits are encountered within the tunnel horizon, an Earth Pressure Balance TBM will be required.

7 Shafts

Based on the anticipated ground conditions and site constraints it is anticipated that the best suited shaft type is the secant pile wall. Secant pile wall shafts are formed by a series of interlocking drilled concrete piles that can be placed to enclose the desired area before the excavation is performed. Initially every other pile (or primary pile) is installed. After the concrete in these piles has cured, the intermediate or interlocking piles are constructed in between every two existing piles to provide a continuous wall. The piles are usually constructed using foundation drill rigs with either continuous flight or bucket auger drills. The drilled holes can be cased or drilling slurry can be used to support the surrounding soil. After drilling the hole, steel reinforcement (H-pile) can be placed in the drilled hole, and then the hole is filled with concrete using the tremie method. The drilled piles are typically 2 to 3 feet in diameter. The secant pile method is used primarily where unstable soils (i.e. fill and alluvial soils) and a high groundwater table are present. Because of the low level of noise and vibration associated with the pile drilling operation and the relatively limited construction area required, the secant pile technique is an attractive method for shaft construction in congested urban settings.

7.1 Launching Shafts

The launching shaft serves as the starting point for the tunneling operations; it is also the point of removal for the muck; and it provides access for below grade services that must support construction operations. The tunneling equipment, guidance equipment, and pumps are also housed within this shaft. For pipe jacking methods, part of the function of the launching shaft includes distributing the jacking loads evenly to the adjacent ground without any excessive deformation. The launching shaft must also accommodate any planned hydraulic structures that will be constructed in the shaft after tunneling is completed.

The layout area supporting the construction operations at the launching shaft must provide sufficient space for the equipment, which may include operator control cabin, power supply equipment, the crane or gantry system, muck processing area, and storage to include adequate supply of tunneling pipe and incidentals. Allowance should be made for parking space of key construction personnel and owner representatives.

7.2 Retrieval Shafts

The retrieval shaft serves as the extraction point for tunneling equipment at the conclusion of the tunneling. This shaft must be constructed prior to starting the tunneling to eliminate delays regarding retrieval of the tunneling equipment; however, the receiving shaft can be covered with a steel plate or structural decking to allow traffic lanes to remain open while the shaft is not being used. The receiving shaft must also accommodate any planned hydraulic structures and pipe connections.

8 Construction Staging Area Considerations

Staging areas should consider activity related to both tunnel and drop shaft construction and take into account equipment and material supply and storage needs. For general planning purposes about 0.5 acres will be adequate for drop shaft construction staging. It may entail that employees may have to park off-site plus limited material storage space would be available.

Assuming tunnels in the 12-foot diameter range about 2 acres of staging space may be considered adequate for planning purposes at launching shaft sites. Office space will be constrained and employee off-site parking will be required. Onsite material storage may be an issue that would need to be evaluated as well muck storage if non-haul hours are instituted.

Other general factors that will need to be considered as part of staging are community related issues such as haul hours, noise, vibrations, dust and light.

8.1 Tunneling – Staging Considerations

Staging area requirements will vary based on selected tunnel size and tunneling method. In general, space requirements for 6-ft diameter tunnels installed using either pipe jacking or microtunneling will be less than a 12-ft diameter constructed using utility tunneling methods. Occupancy will include use of temporary and permanent easements. Typical tunneling equipment and material include the following:

<u>Pipe jacking / Microtunnel with TBM</u>

Entry shaft/jacking pit area equipment / trailers

- Contractor / owner representative trailers with parking for staff
- Crane to lower jacking frame and equipment, machine, lower pipe, lower advance materials, remove muck
- Electrical power equipment / transformers, switchgear
- Hydraulic power pack to supply power to the excavator shield
- Bentonite/slurry plant
- Loader to service jacking pit / load muck
- Rolling stock, muck cars, and haul units
- Ventilation fan

Entry shaft on site material storage for at least two or three days of production

- Jacking Pipe
- Hydraulic lines to advance shield
- Rail, ties and spreaders
- Slurry pipes to advance shield
- Vent line
- Power cable
- Conex box
- Muck bin

<u>Pipe jacking / Microtunnel with MTBM</u>

Entry shaft/jacking pit area equipment / trailers

- Contractor / owner representative trailers with parking for staff
- Crane to lower jacking frame and equipment, machine, lower pipe, lower advance materials
- Electrical power equipment / transformers, switchgear
- Operator control and power distribution container
- Bentonite/slurry plant and separation tank
- Loader to service jacking pit
- Ventilation fan

Entry shaft on site material storage for at least two or three days of production

- Jacking Pipe
- Hydraulic lines to advance shield
- Slurry supply and return pipes to advance shield
- Vent line
- Power cable
- Conex box

<u>Utility tunneling</u>

Entry shaft equipment / trailers

- Contractor / owner representative trailers with parking for staff
- Crane to lower TBM and backup gear, equipment, lower pipe, lower advance materials, remove muck, service shaft
- Hydraulic crane to service yard
- Electrical power equipment / transformers, switchgear
- Mechanical / electrical shop
- Grout plant / silo
- Compressor
- Generator
- Water treatment facility
- Loader to service shaft
- Rolling stock - locomotives, mantrip, flatcar, muck car, grout car
- Ventilation fan
- Muck bin
- Aggregate bin

Entry shaft on site material storage for at least two or three days of production

- Precast segments (one pass) and product pipe (two pass)
- Rail / ties / spreaders
- Air & water line
- Vent line
- Power cable
- Conex box

Exit shaft area equipment (inclusive of all tunneling methods)

- Crane to remove machine
- Loader to service receiving pit / load trucks for demobilization
- Ventilation fan

9 Underground Storage Tanks

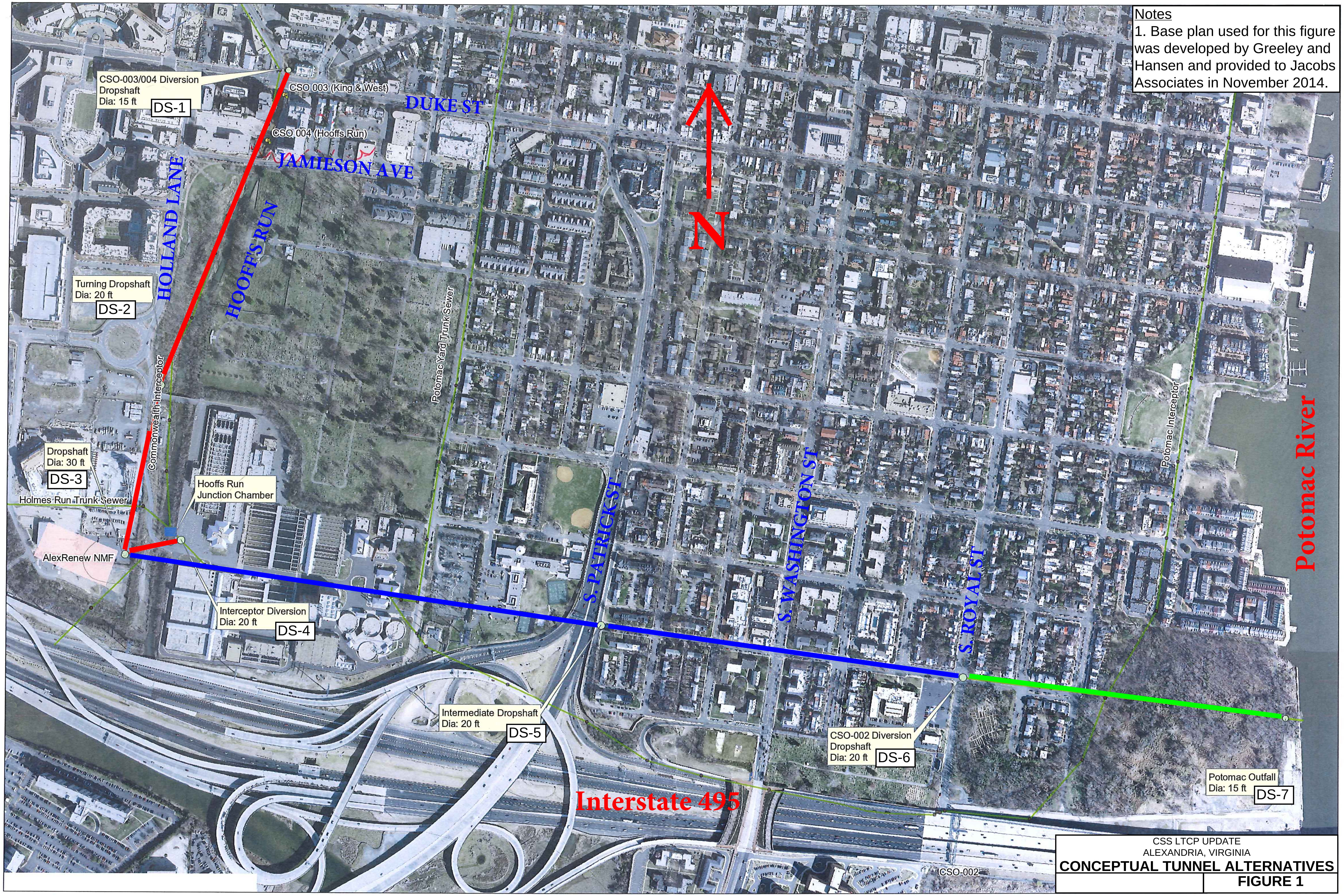
A below grade storage tank option concept is under consideration as a potential alternate to tunnel storage. The proposed location would be in the proximity of Outfall 002 in a relatively level parcel at the southern end of Royal Street. The bottom of the tank would require excavation to about 20 feet below existing grades.

Anticipated ground conditions are similar to those described for the tunnel concepts above and include Fill underlain by Alluvium, Terrace and Potomac deposits. The bottom of the storage tank would most likely be in the Alluvium deposits.

Design – the primary storage tank design considerations include foundation support, resistance to uplift and wall design. Based on the anticipated soil conditions and groundwater levels, it is envisioned that deep foundation support will be required to provide both support for the tank and resistance to uplift. Typical foundation types include drilled shafts and micropiles. Drilled-type piles are preferable to driven piles due to reduced vibration levels and potential disturbance to the temporary support of excavation walls. The walls of the storage tank will need to be designed for a combination of soil and groundwater pressure. It is anticipated that the permanent walls will be fairly rigid.

Construction - to facilitate construction of the storage tank a temporary support of excavation wall and dewatering will be necessary. An impermeable wall type such as a slurry wall or secant pile wall with tie backs would be feasible.

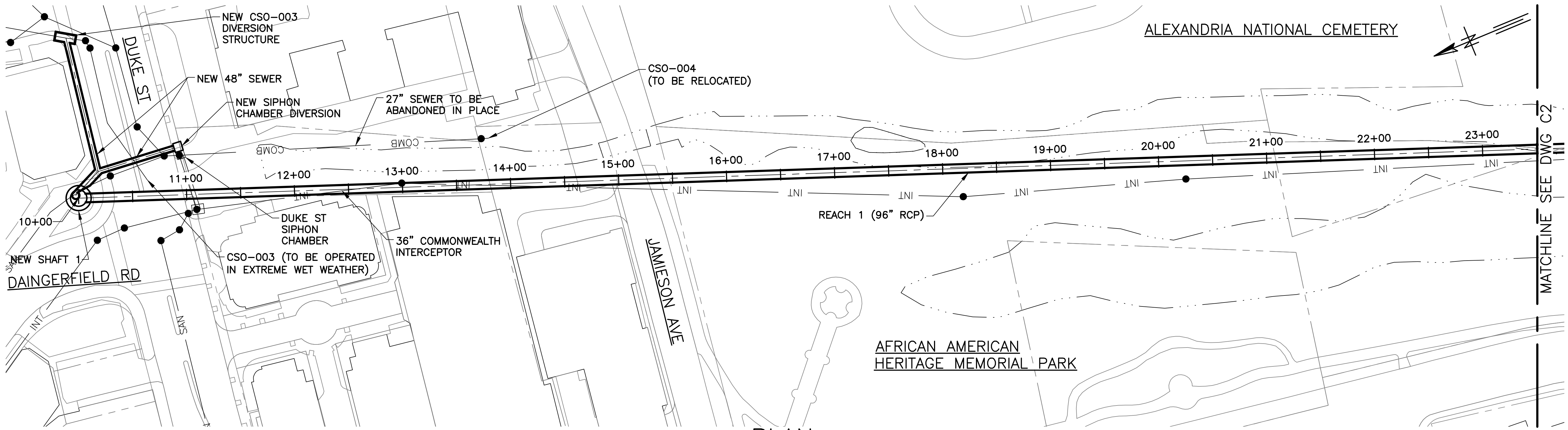
We note that the walls of the storage tank structure could be constructed as slurry walls, which could also be used for excavation support. Since slurry walls would be part of the permanent structure they would require design by the engineer rather than the contractor. Under this scenario, the engineer would design the slurry wall to the penetration depths required for use as the contractor's temporary excavation support system, but also could allow the contractor the option of extending the wall depth for groundwater cutoff and dewatering purposes. The slurry wall option would not only benefit in controlling groundwater seepage while serving as excavation support, but would also provide substantial dead weight to resist uplift forces thereby reducing or possibly eliminating the need for uplift resistance elements.



CSS LTCP UPDATE
ALEXANDRIA, VIRGINIA
CONCEPTUAL TUNNEL ALTERNATIVES
FIGURE 1

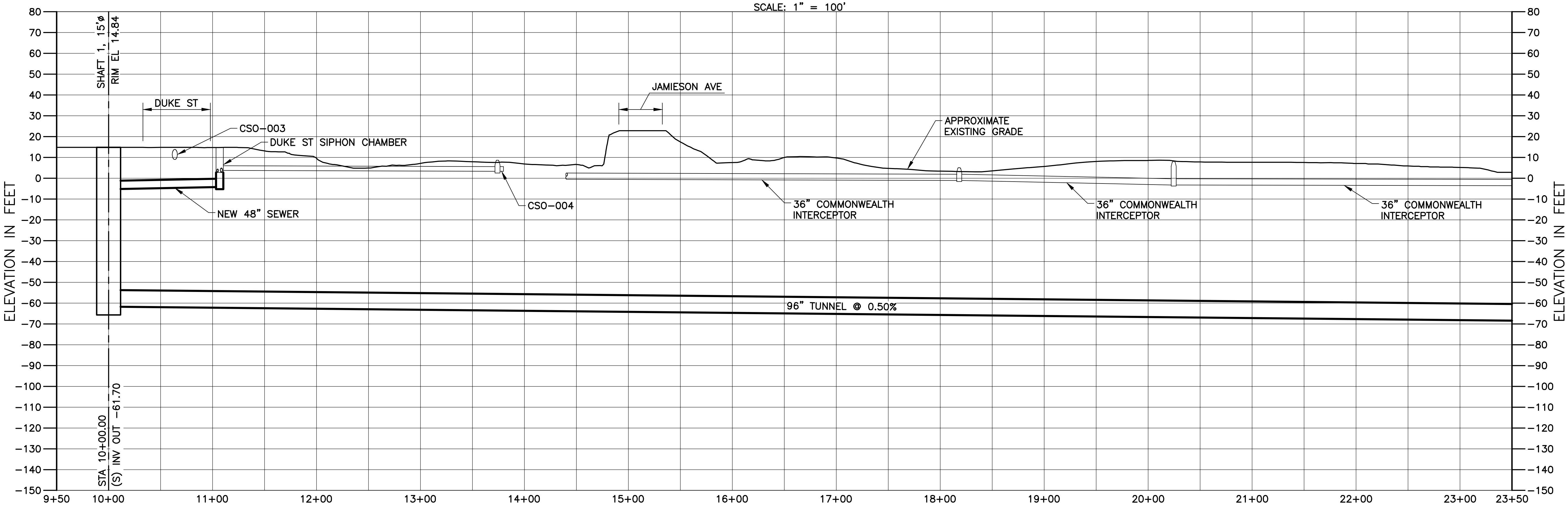
Attachment B

CSO-003/004 Tunnel from CSO-003/004 to AlexRenew WRRF (Alternative T1)



PLAN

SCALE: 1" = 100'



STATION

PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'

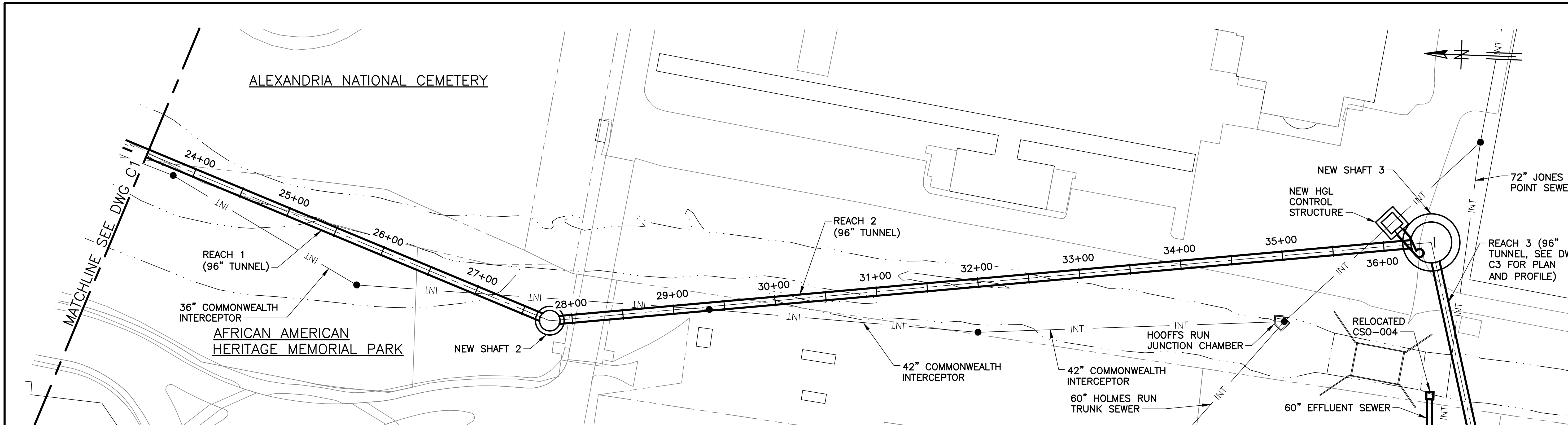
0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T1

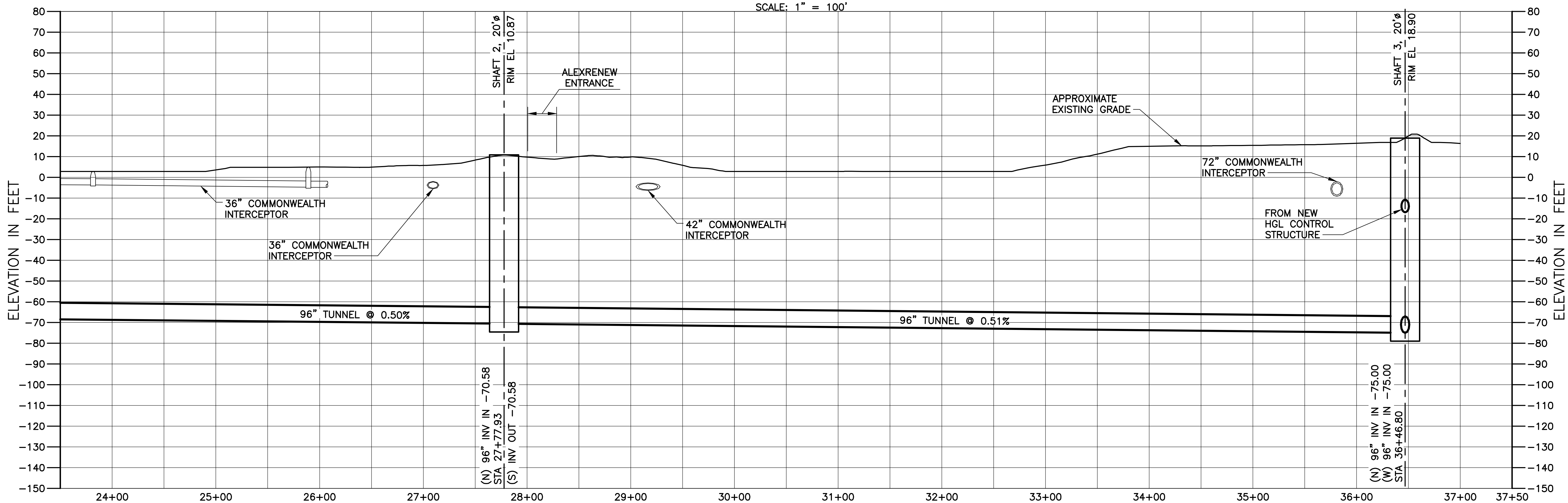
DRAWING: C1

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T1-C01.DWG 04/08/2015 10:33:05 AM



PLAN

SCALE: 1" = 100'



STATION

PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

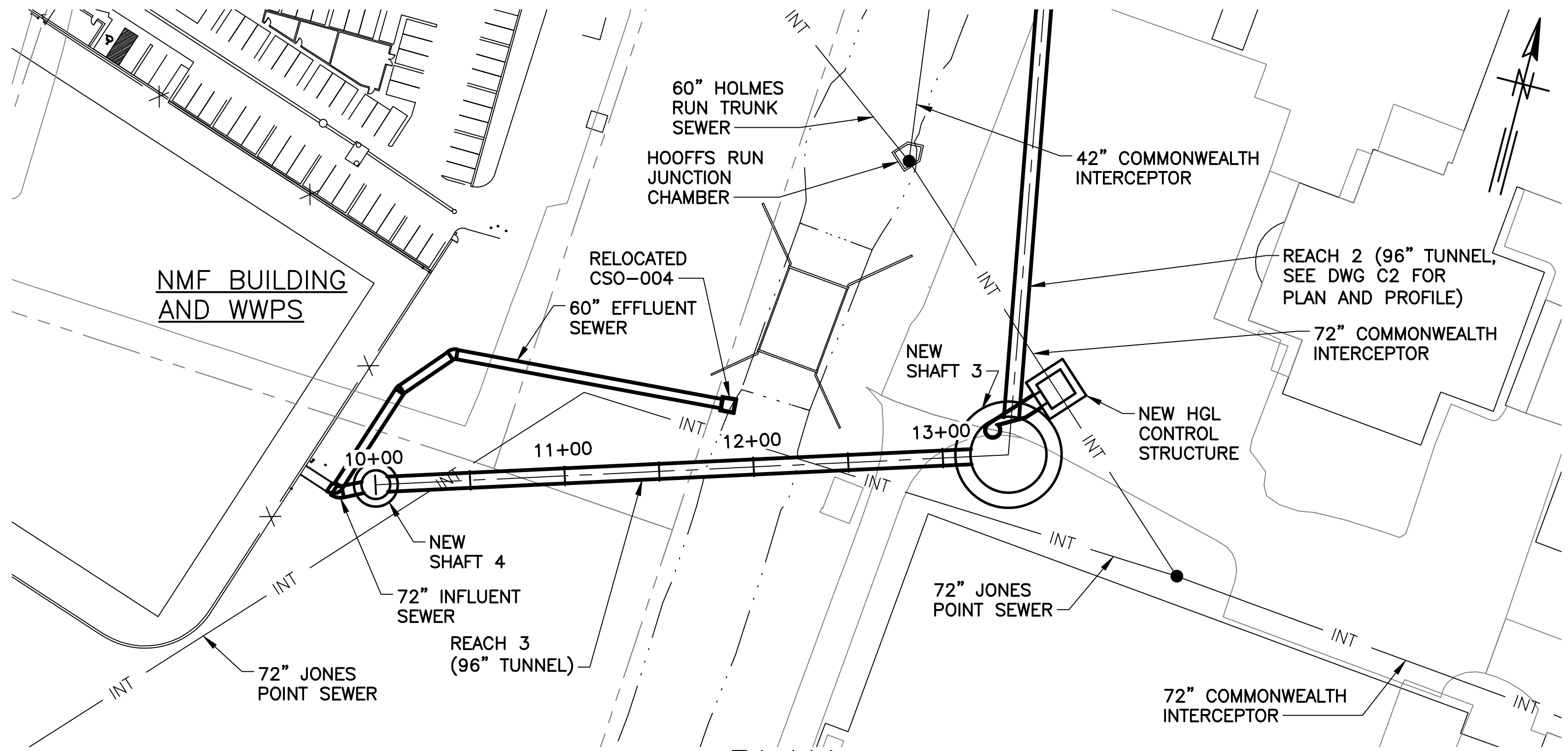
0 50 100 FT
1"=100'
0 50 FT
1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T1

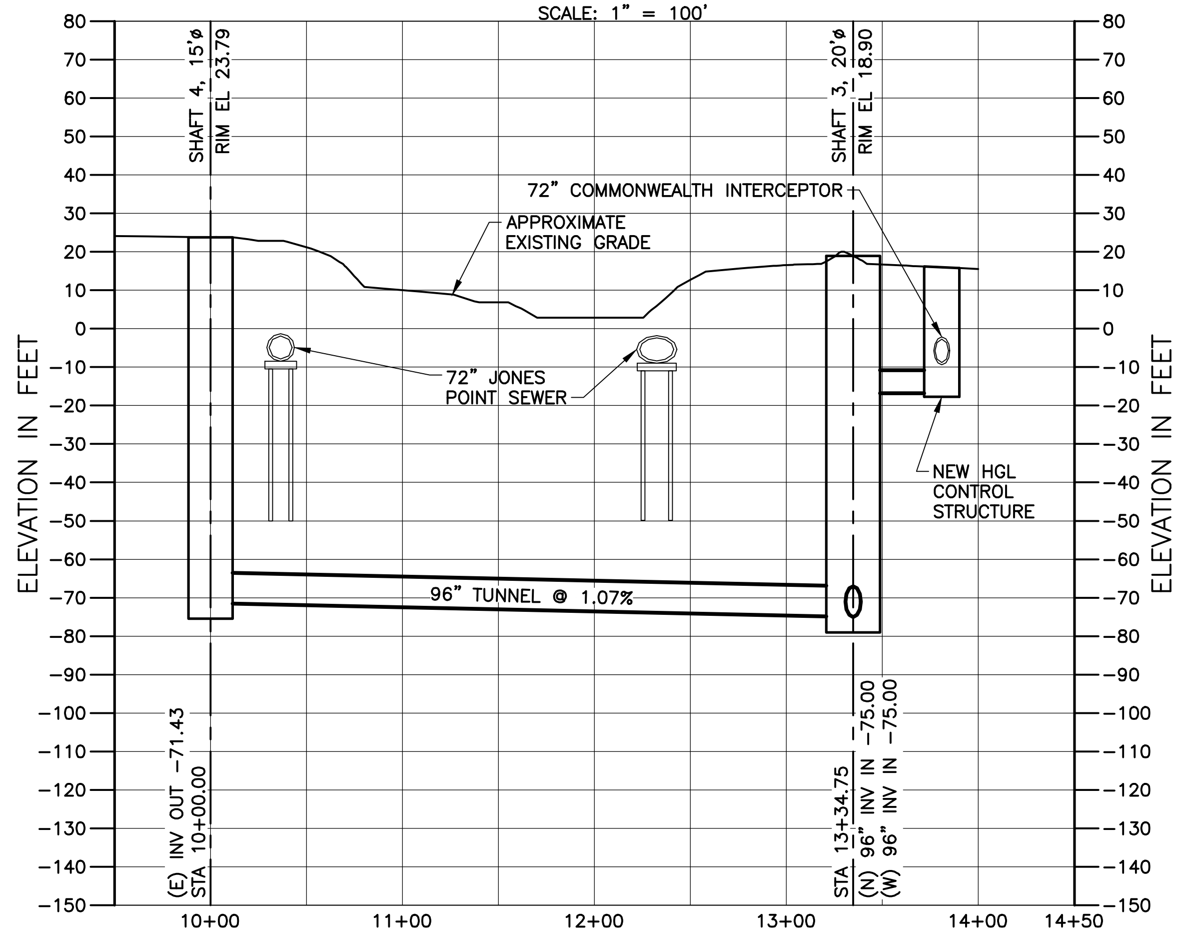
DRAWING: C2

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T1-C02.DWG 03/11/2015 1:33:57 PM



PLAN

SCALE: 1" = 100'



PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

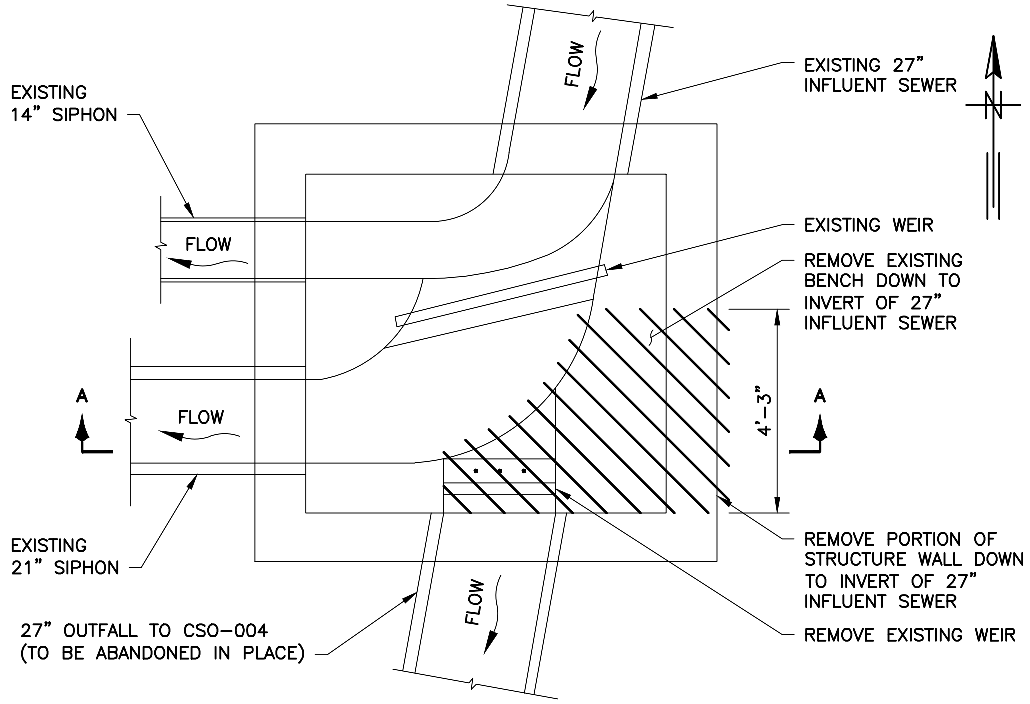
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'
0 50 FT 1"=50'

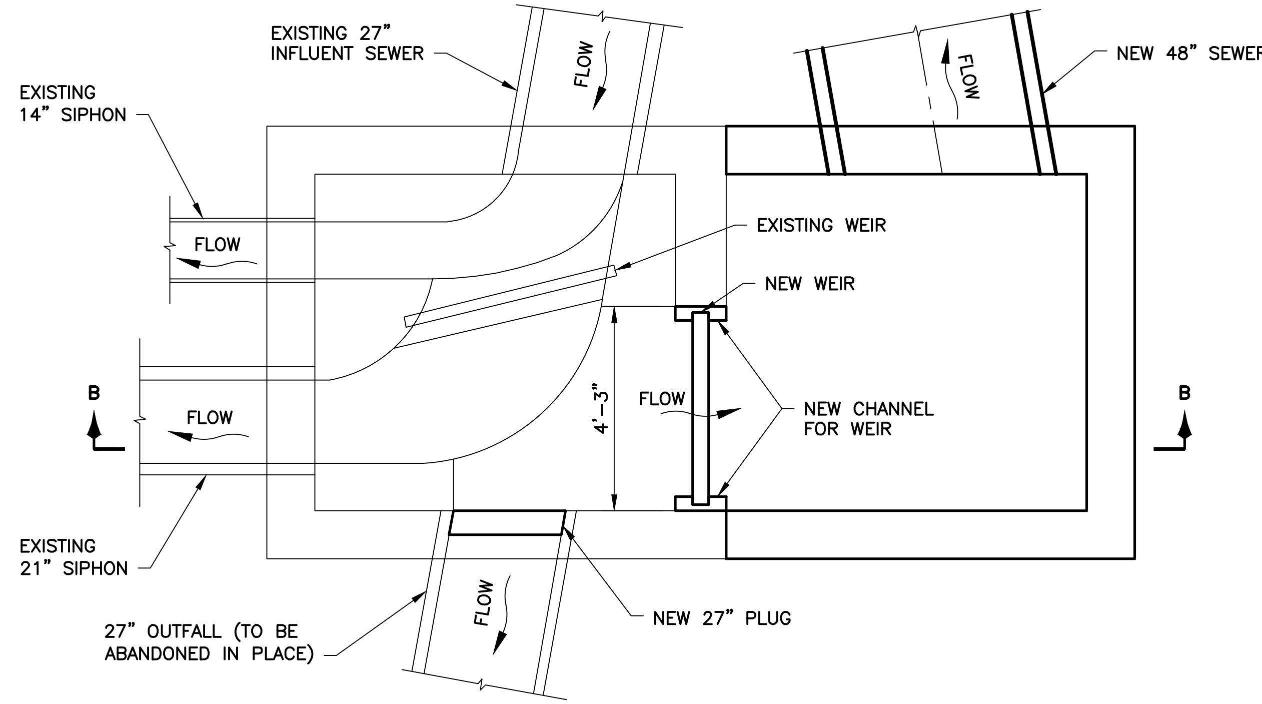
CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T1
DRAWING: C3

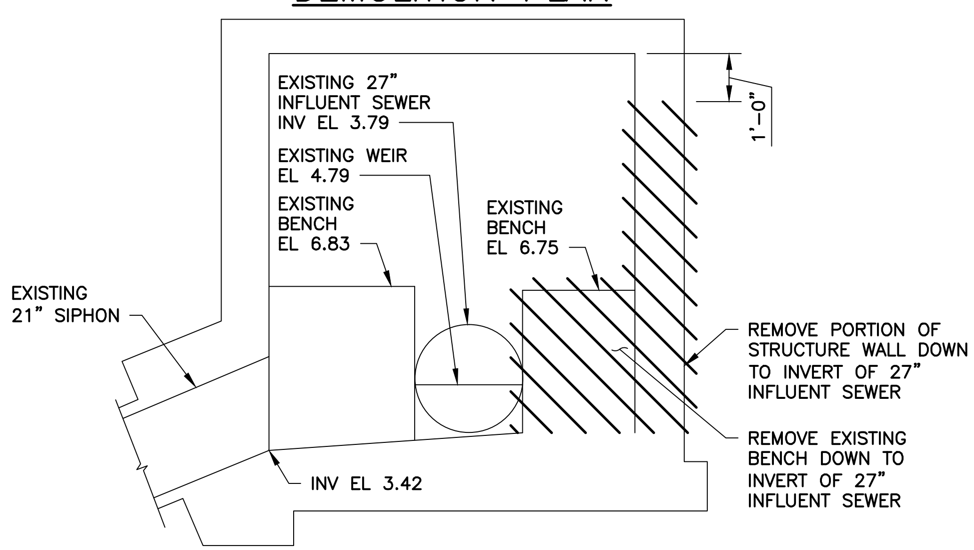
X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T1-C03.DWG 03/11/2015 1:37:13 PM



DEMOLITION PLAN

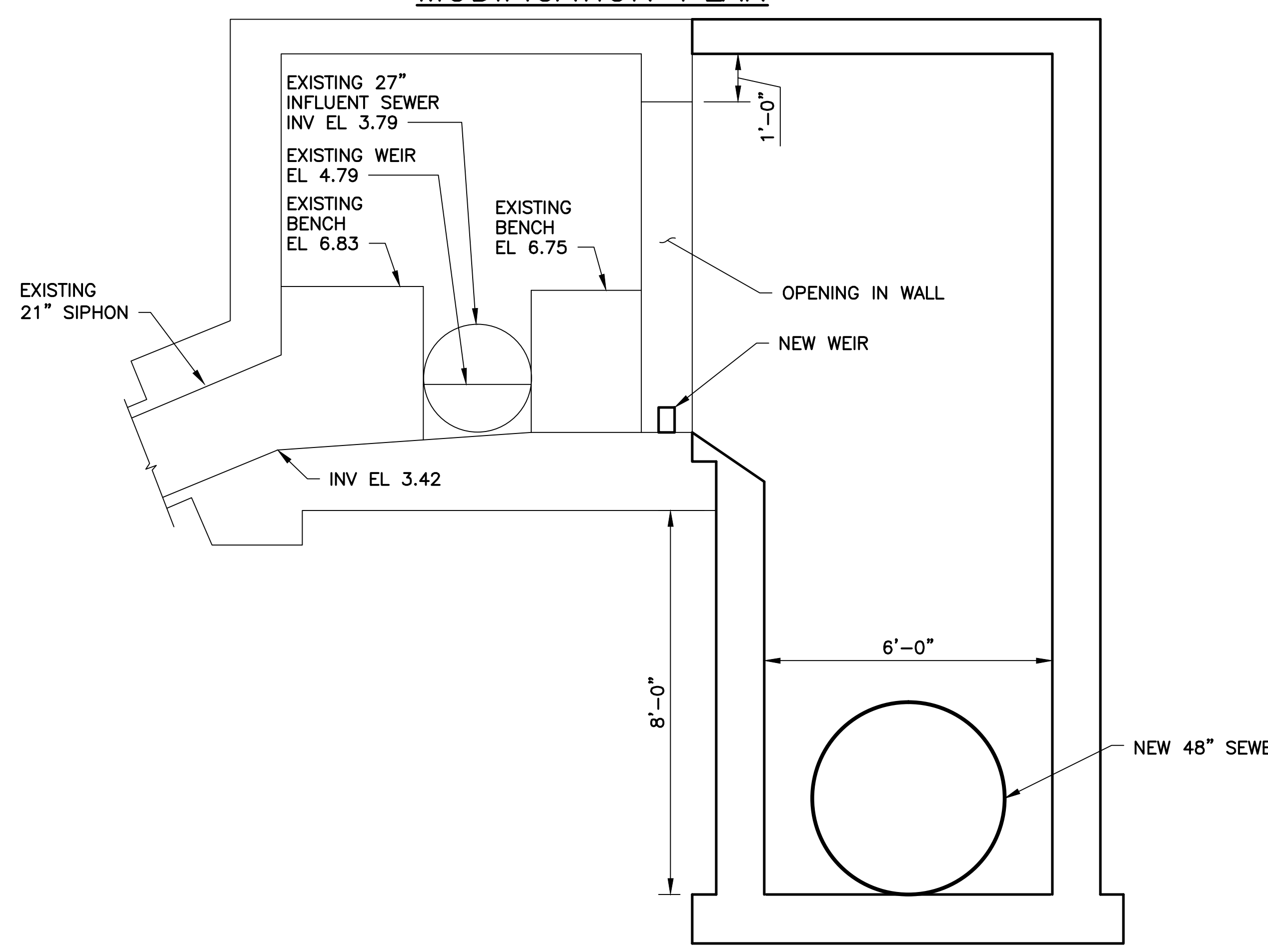


MODIFICATION PLAN



SECTION A – DEMOLITION

DETAIL 1/C4
DUKE ST SIPHON CHAMBER
SCALE: 1/4" = 1'-0"



SECTION B – MODIFICATION

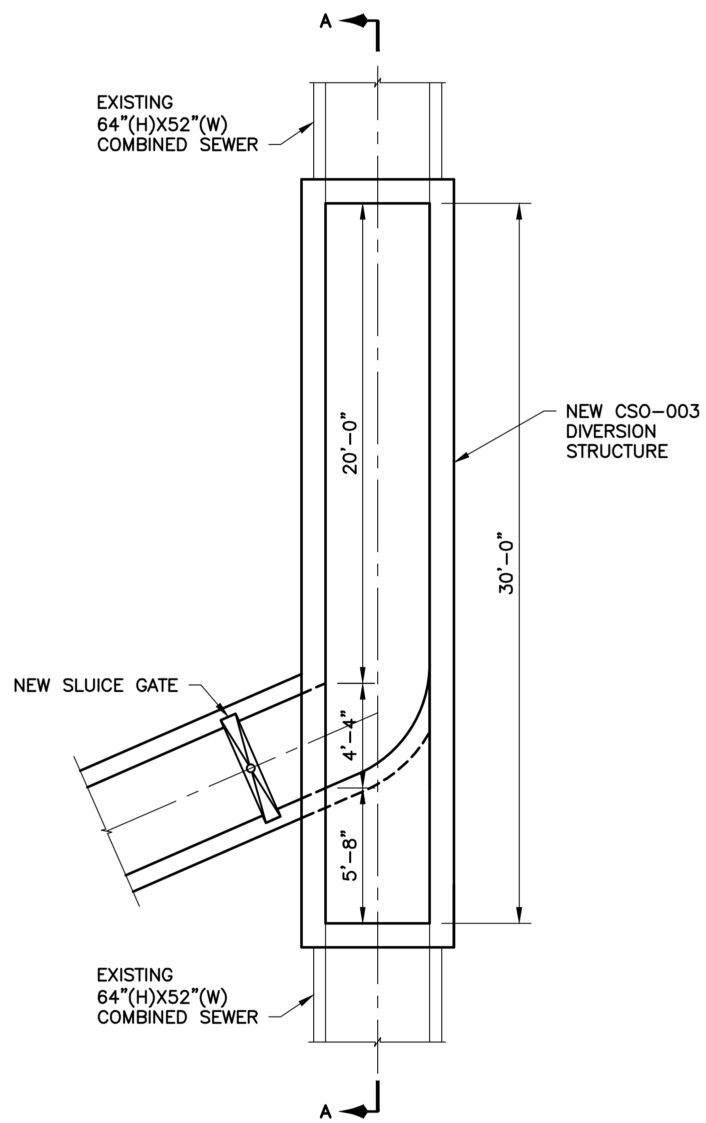
DETAIL 2/C4
DUKE ST SIPHON CHAMBER
SCALE: 1/4" = 1'-0"

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T1-C04.DWG 03/11/2015 1:16:41 PM

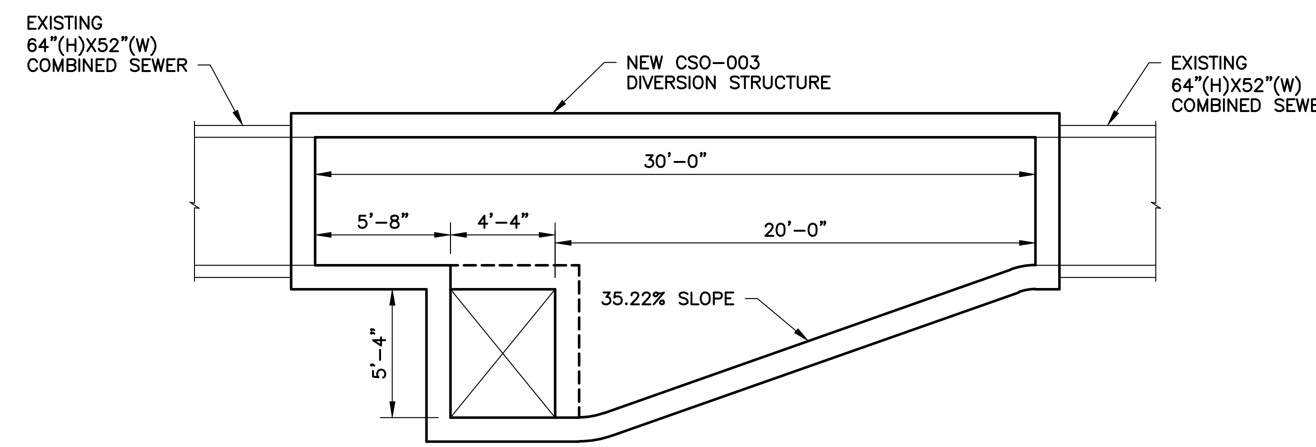
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T1
DRAWING: C4



PLAN



SECTION A

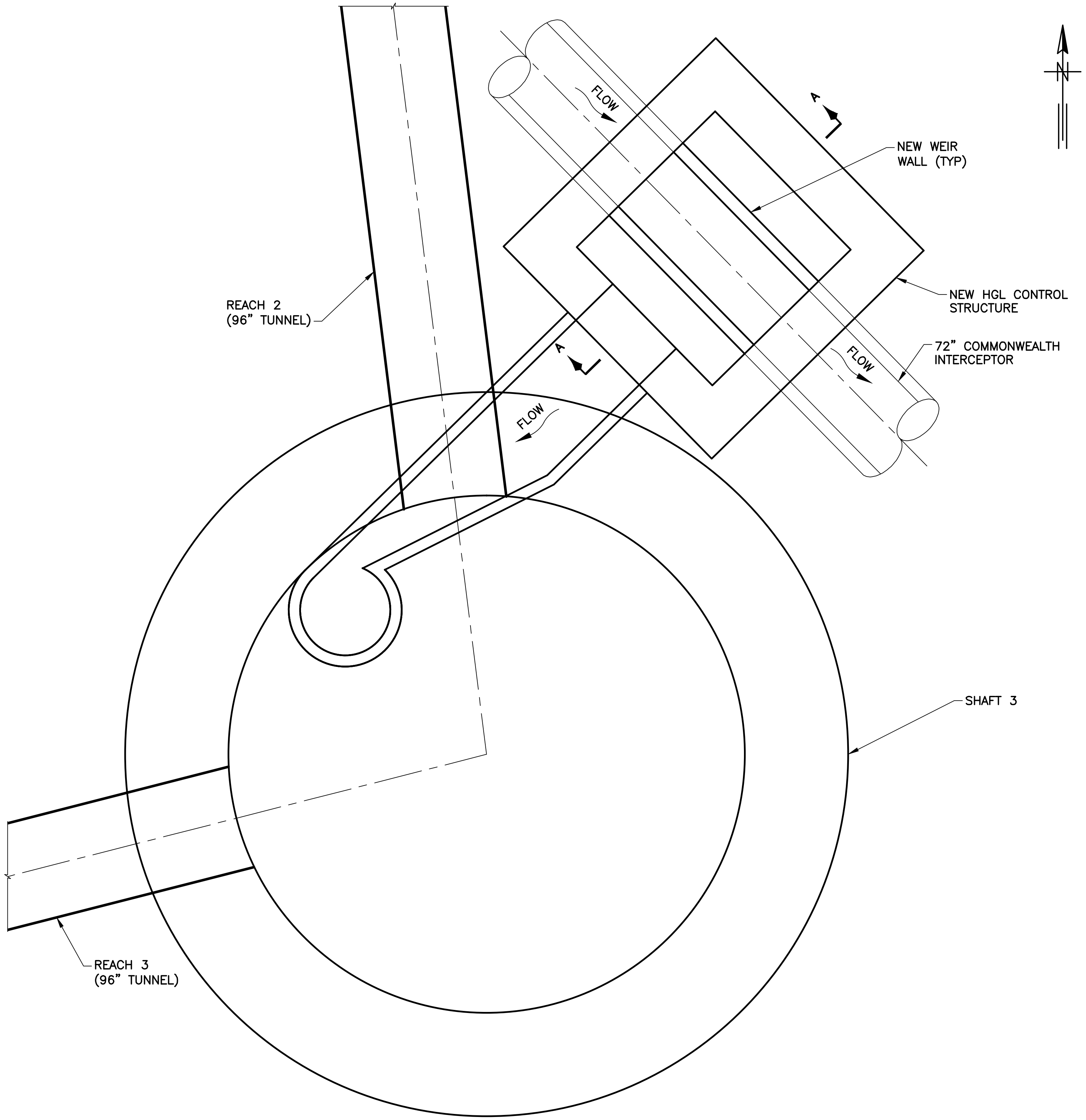
DETAIL 1/C5
CSO-003 DIVERSION STRUCTURE
NOT TO SCALE

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T1-C05.DWG 03/11/2015 1:15:23 PM

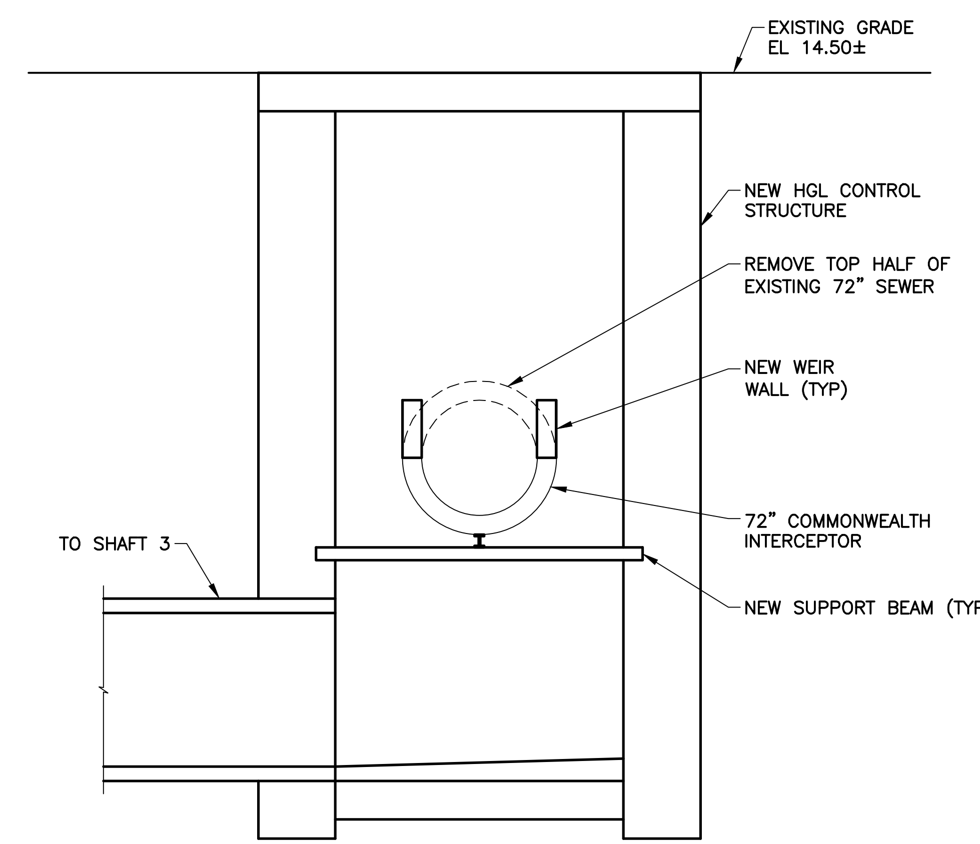
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T1
DRAWING: C5



PLAN



SECTION A

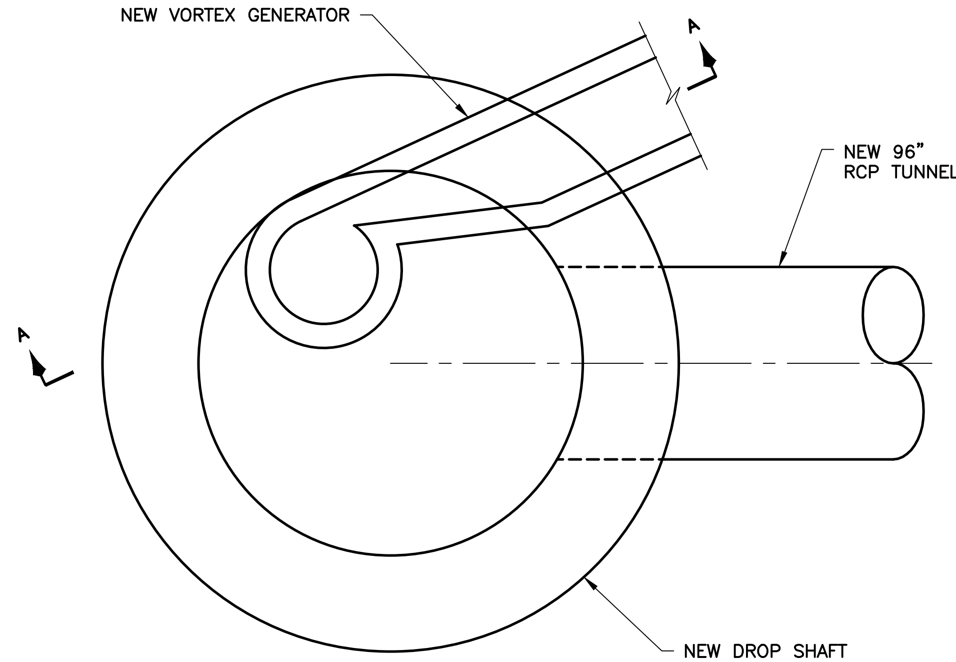
DETAIL 1/C6
NEW HGL CONTROL STRUCTURE
SCALE: 1" = 10'

0 5 10 FT
1"=10'

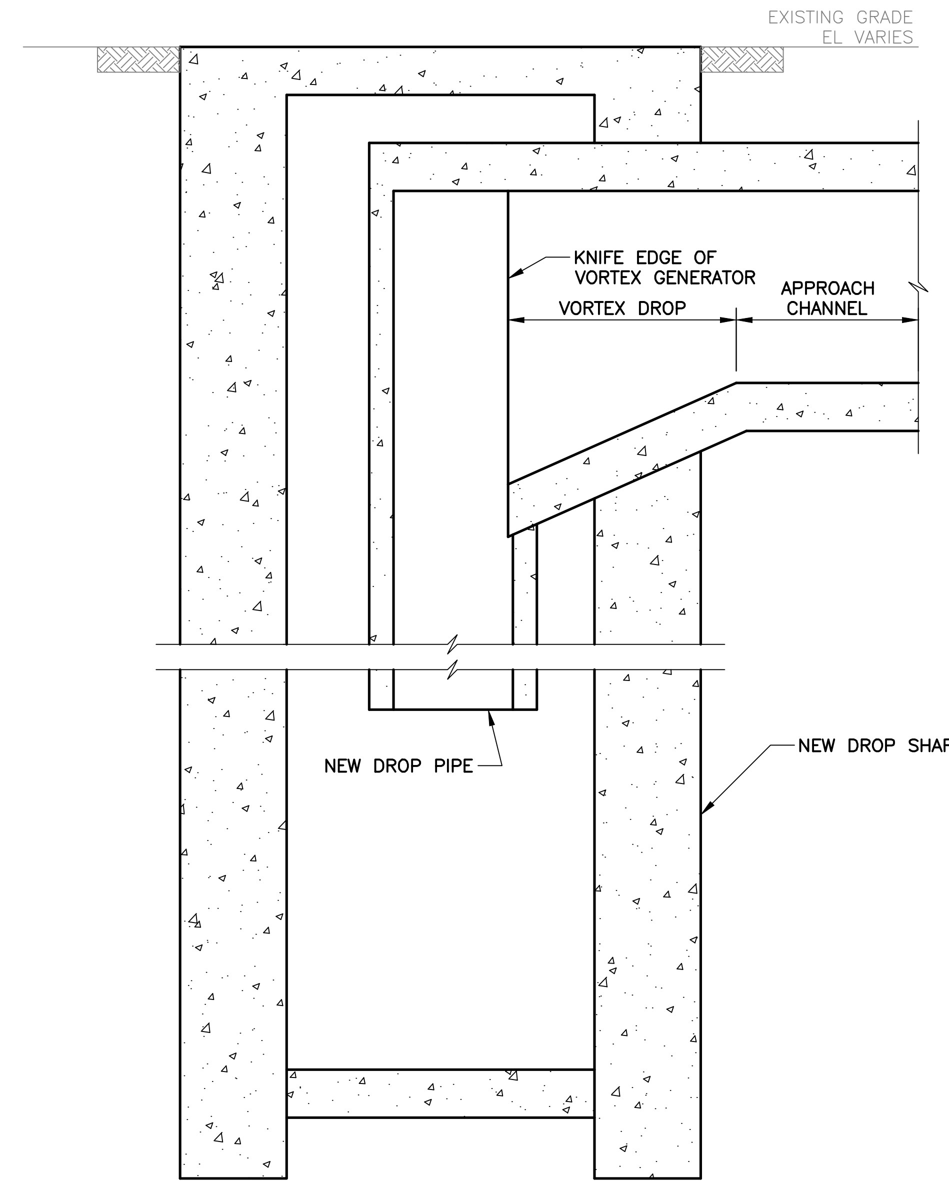
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T1
DRAWING: C6



PLAN



SECTION A

DETAIL 1/C7
TYPICAL DROP SHAFT AND
VORTEX GENERATOR
NOT TO SCALE

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T1-C07.DWG 03/11/2015 12:41:41 PM

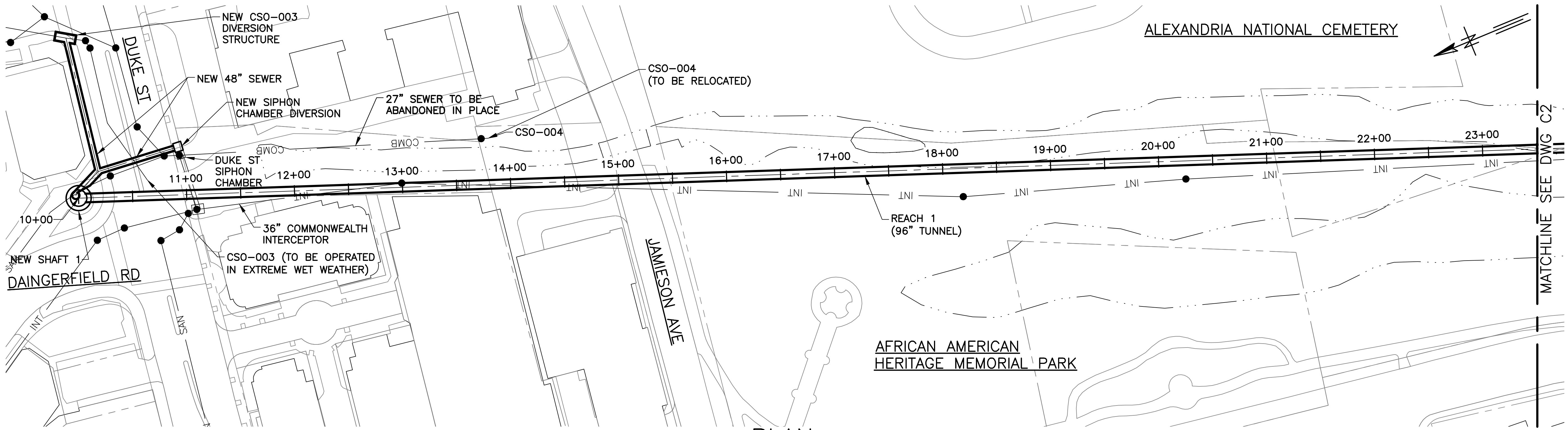
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T1
DRAWING: C7

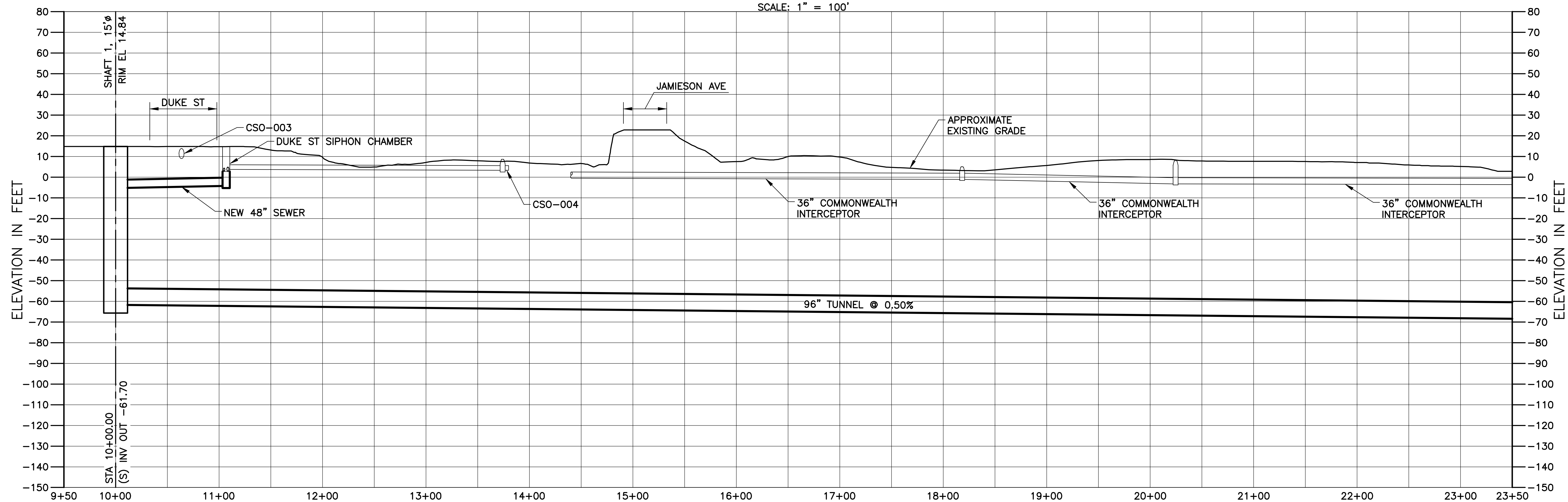
Attachment C

CSO-003/004 Tunnel and CSO-002 Tunnel to AlexRenew WRRF (Alternative T2)



PLAN

SCALE: 1" = 100'



STATION

PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'

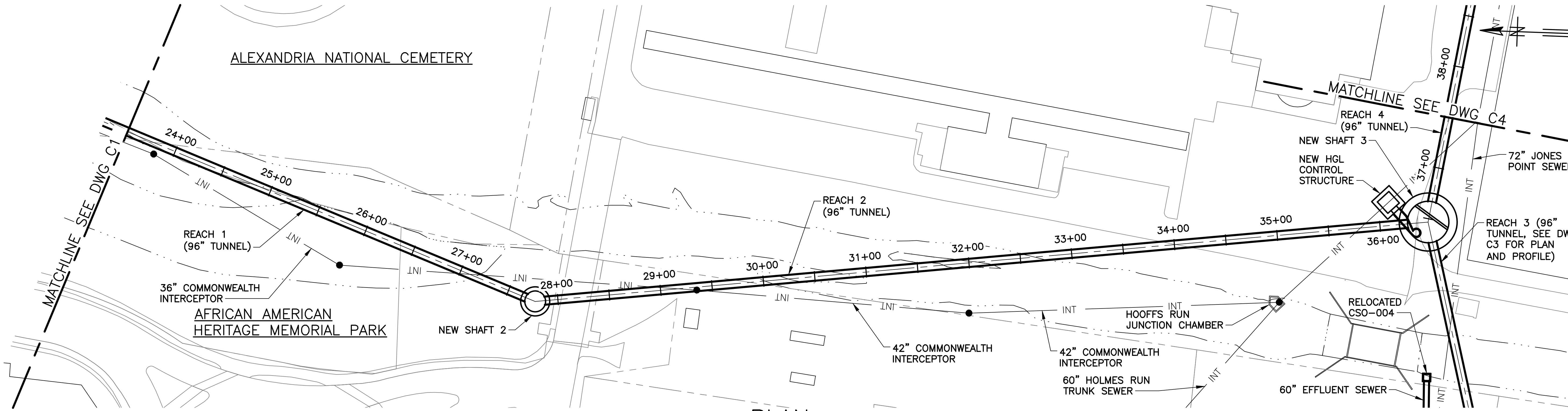
0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T2

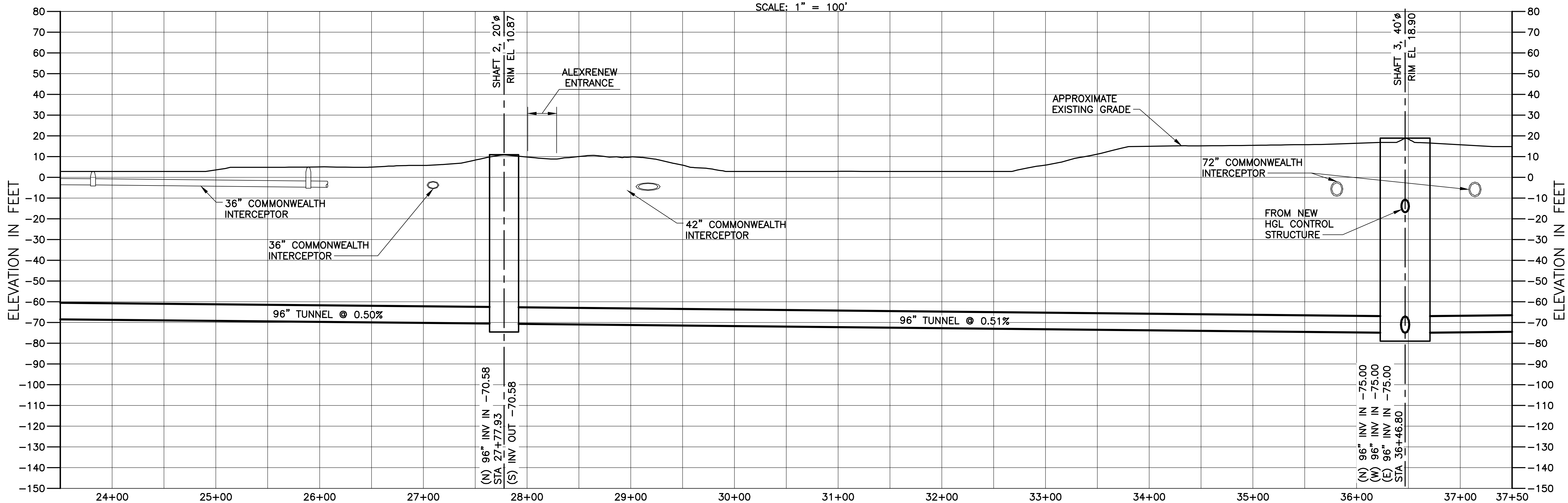
DRAWING: C1

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T2-C01.DWG 04/08/2015 10:36:24 AM



PLAN

SCALE: 1" = 100'

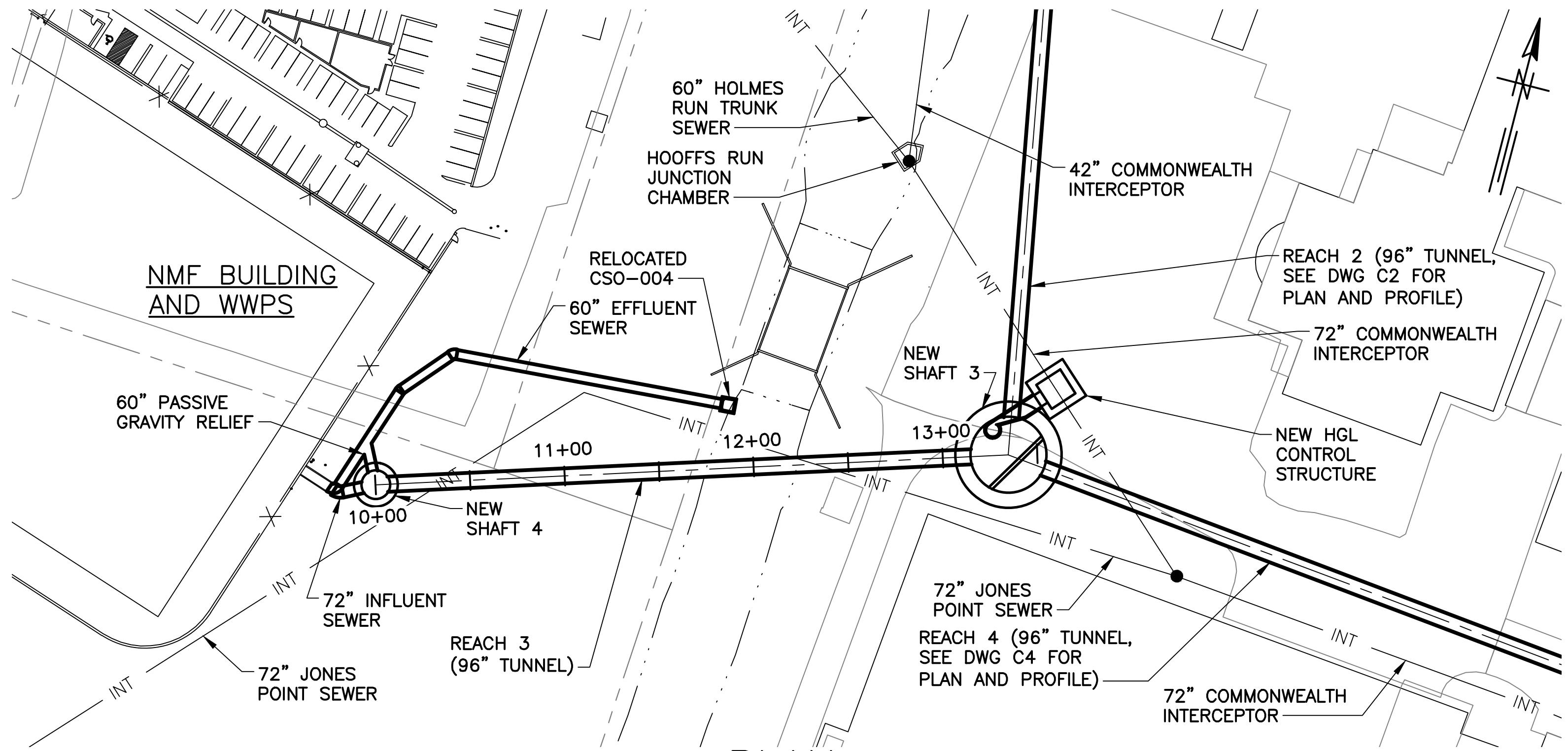


STATION

PROFILE

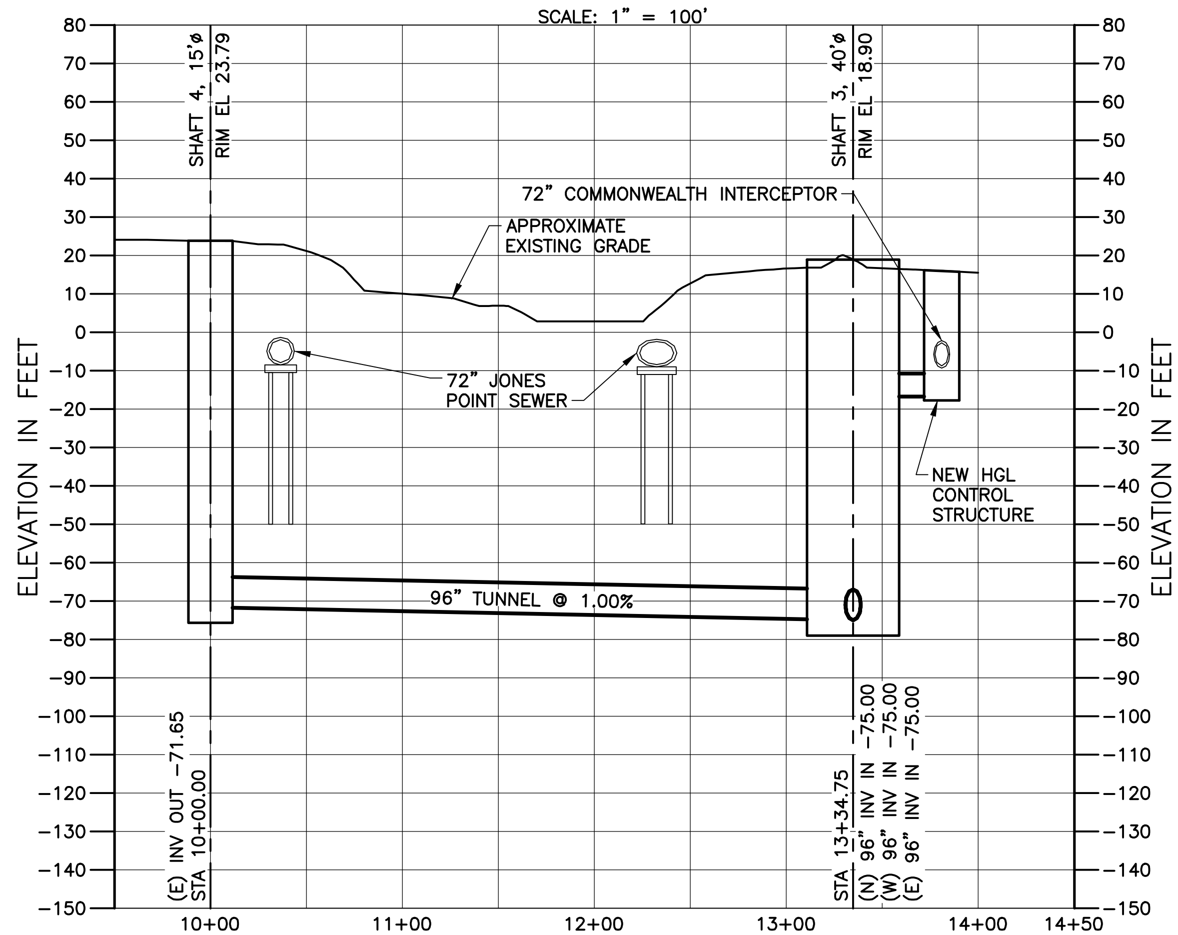
SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

GREELEY AND HANSEN 5301 SHAWNEE ROAD, SUITE 400 ALEXANDRIA, VA 22312	0 50 100 FT 1"=100' 0 50 FT 1"=50'	CITY OF ALEXANDRIA LTCP UPDATE JANUARY 2015	TUNNEL CONFIGURATION ALTERNATIVE T2 DRAWING: C2



PLAN

SCALE: 1" = 100'



PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T2-C03.DWG 03/11/2015 3:52:04 PM

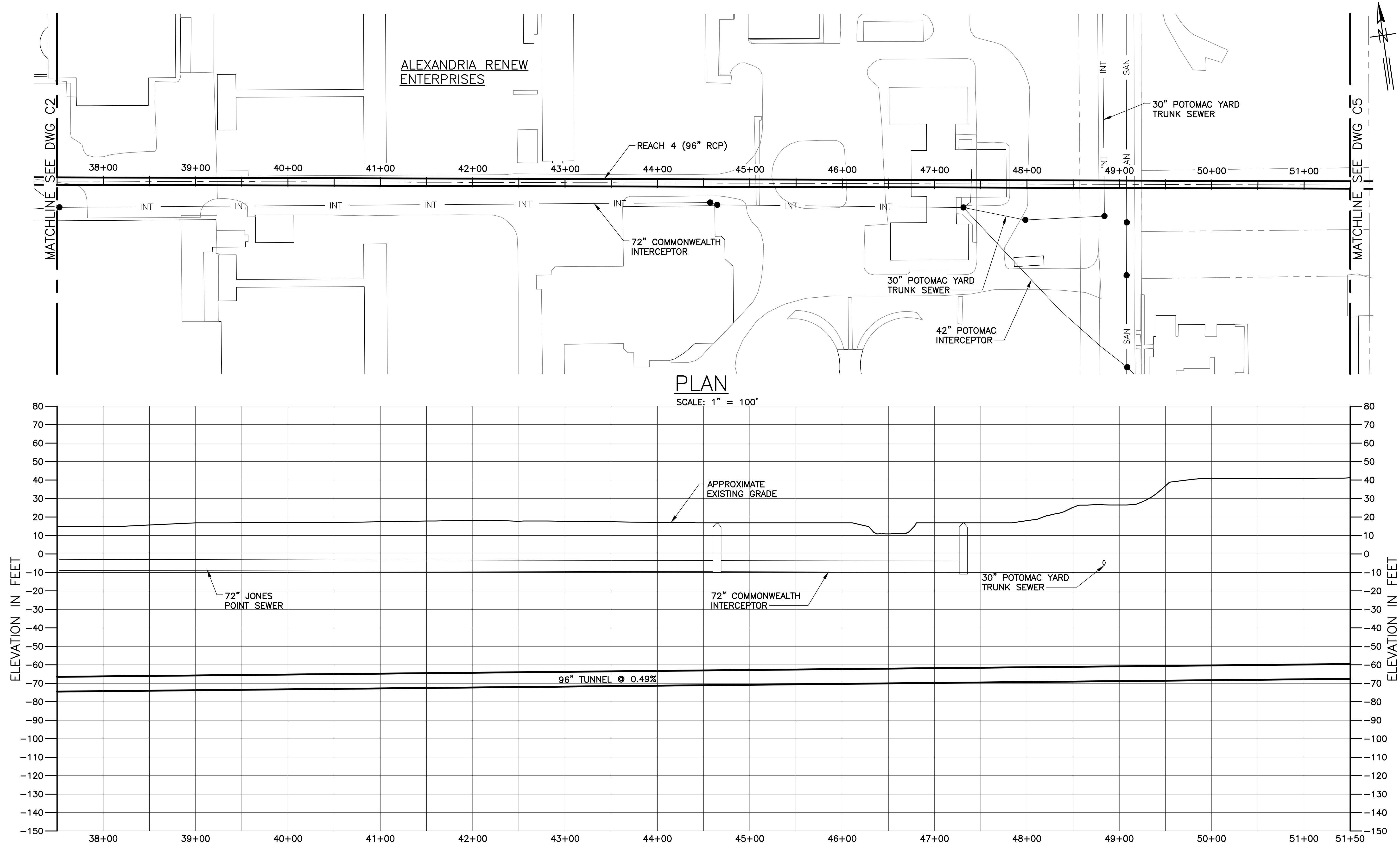
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'
0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T2

DRAWING: C3



PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T2-C04.DWG 03/11/2015 2:14:43 PM

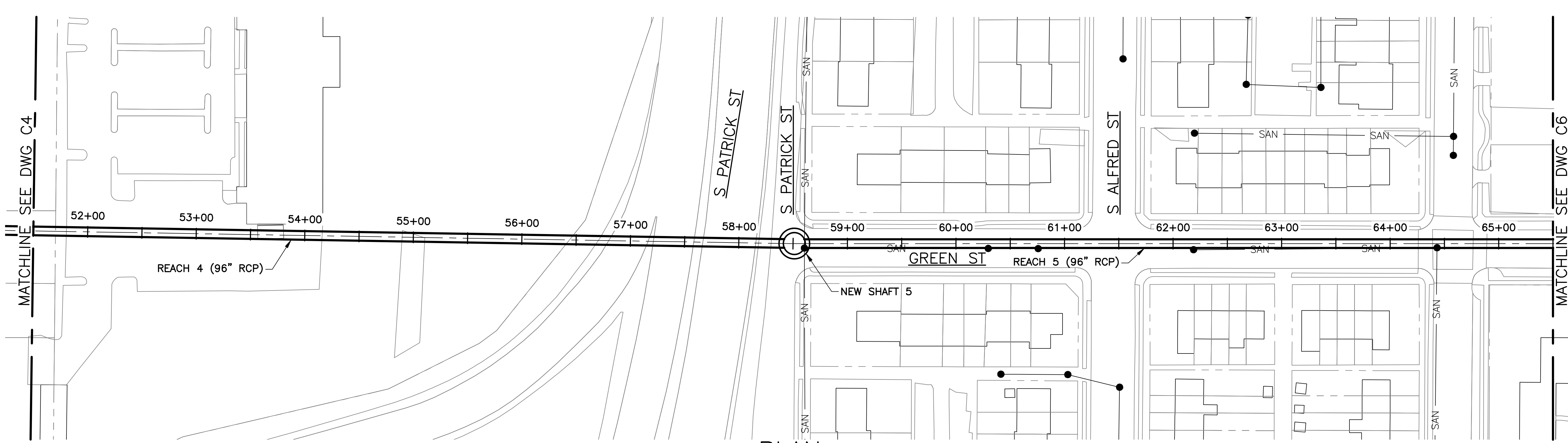
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'
0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

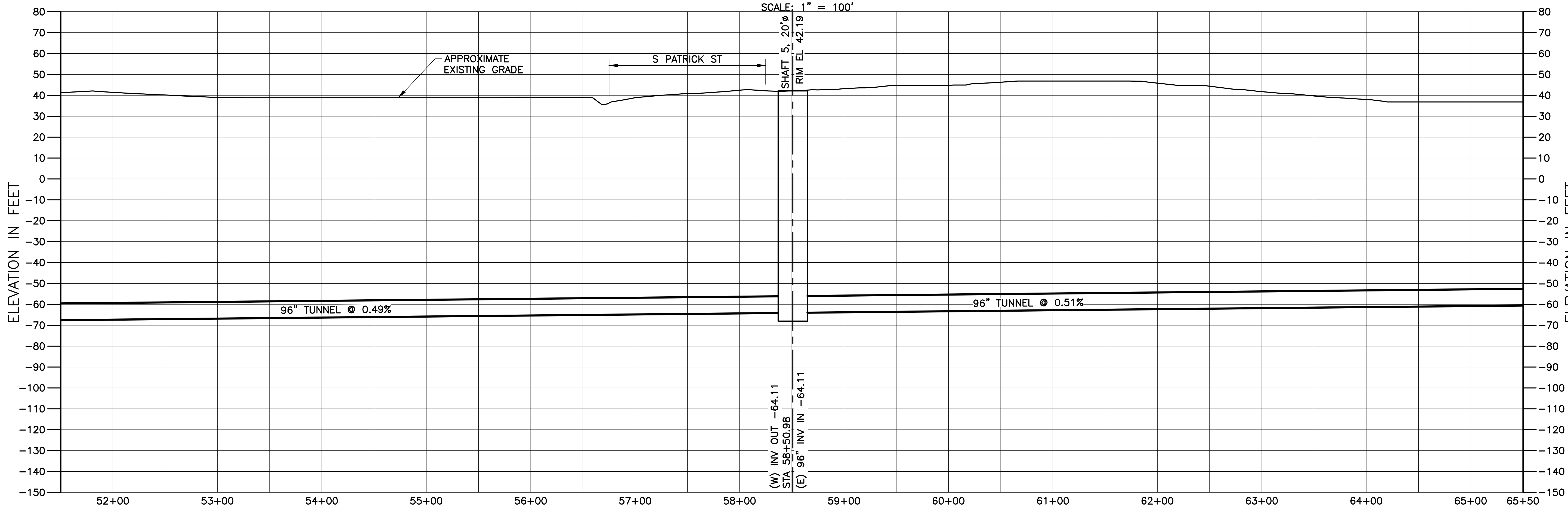
TUNNEL CONFIGURATION ALTERNATIVE T2

DRAWING: C4



PLAN

SCALE: 1" = 100'



STATION

PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T2-C05.DWG 03/11/2015 2:20:24 PM

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'
0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T2

DRAWING: C5

PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T2-C06.DWG 03/11/2015 2:26:59 PM

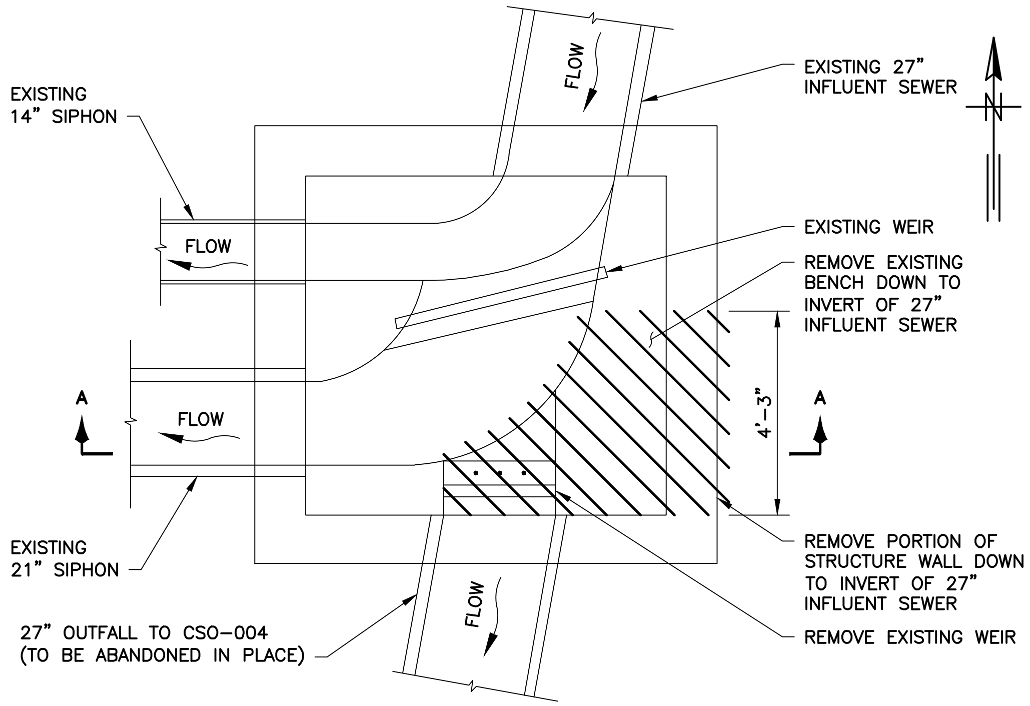
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'
0 50 FT 1"=50'

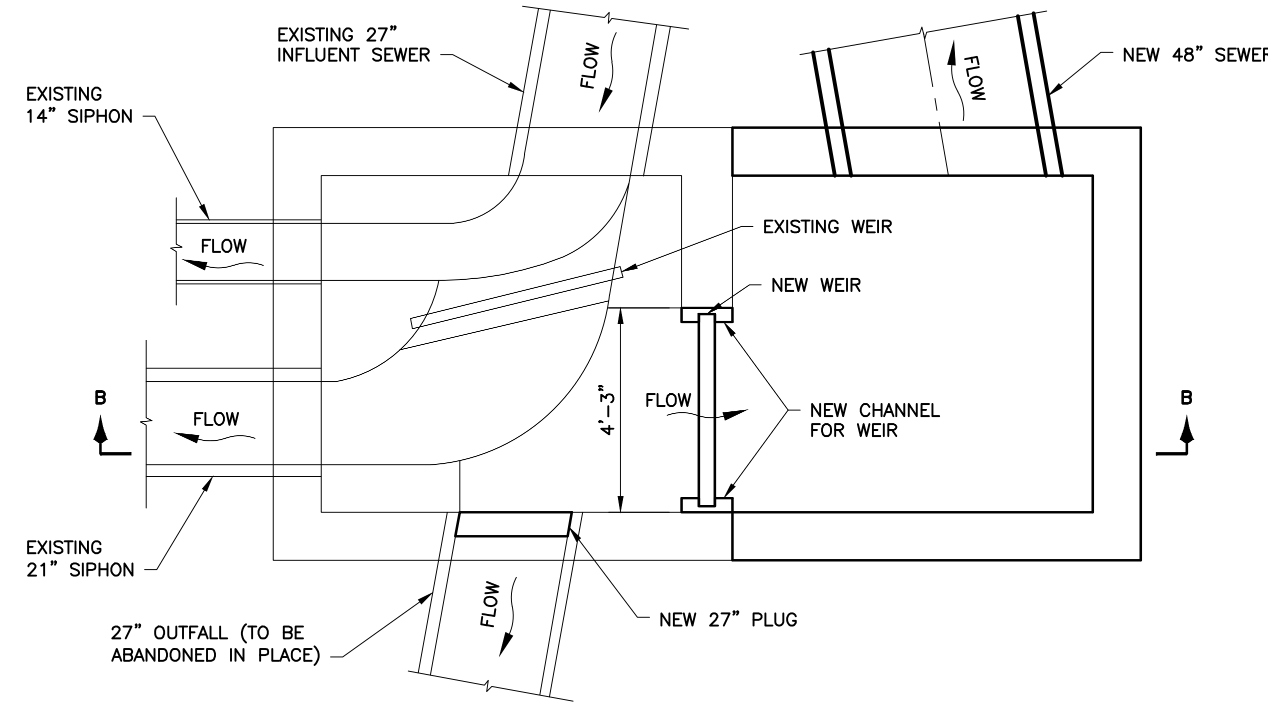
CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T2

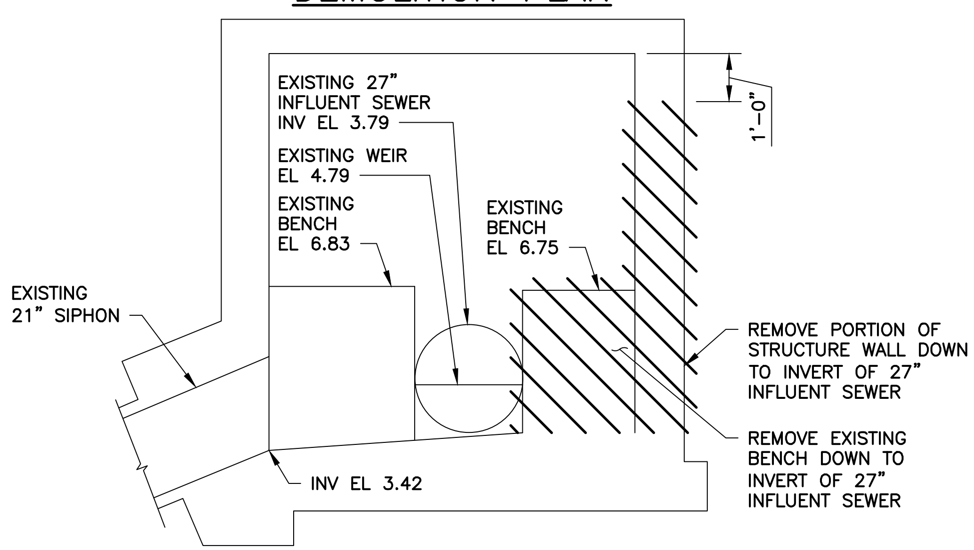
DRAWING: C6



DEMOLITION PLAN



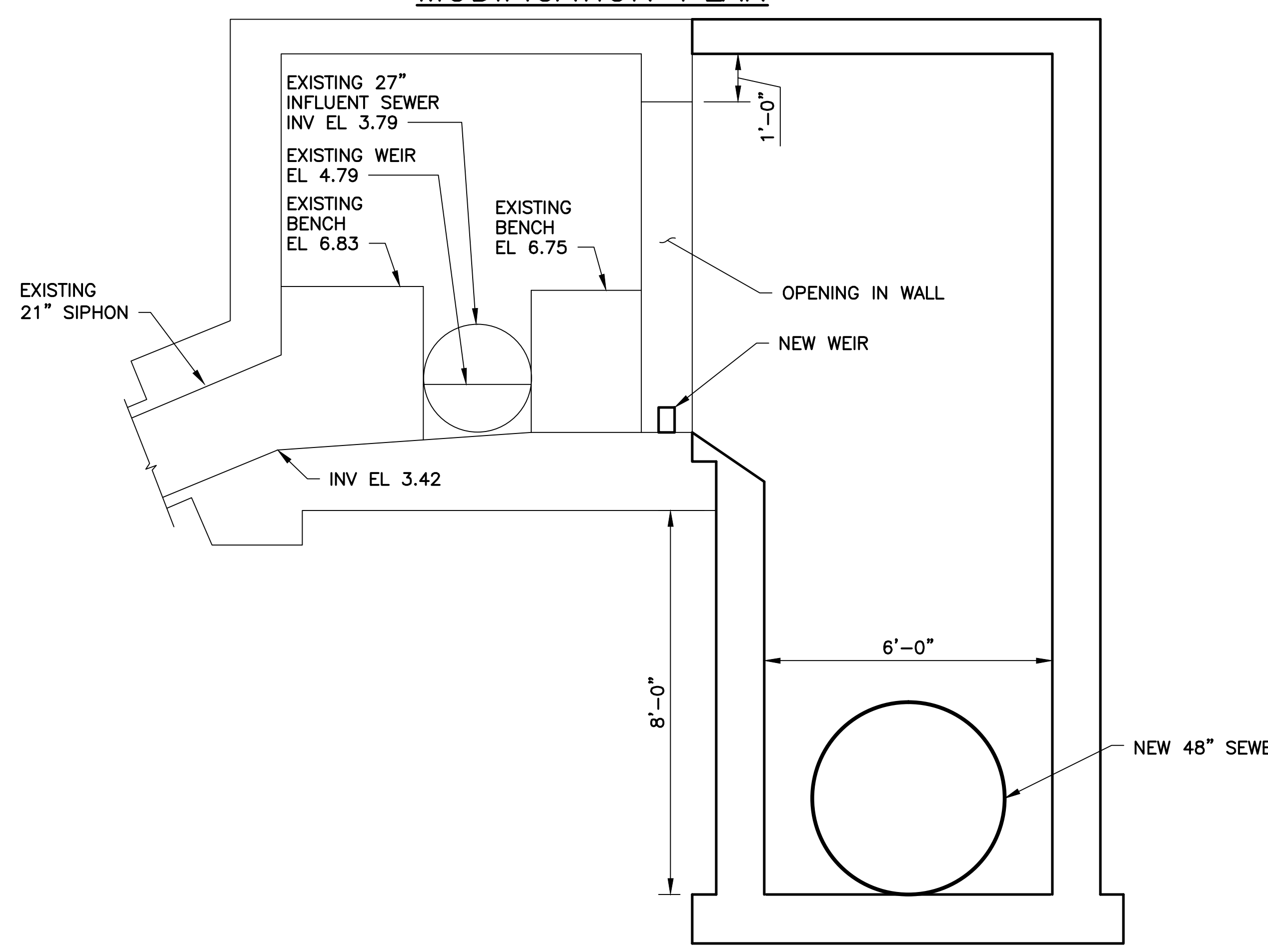
MODIFICATION PLAN



SECTION A – DEMOLITION

DETAIL 1/C7
DUKE ST SIPHON CHAMBER

SCALE: 1/4" = 1'-0"



SECTION B – MODIFICATION

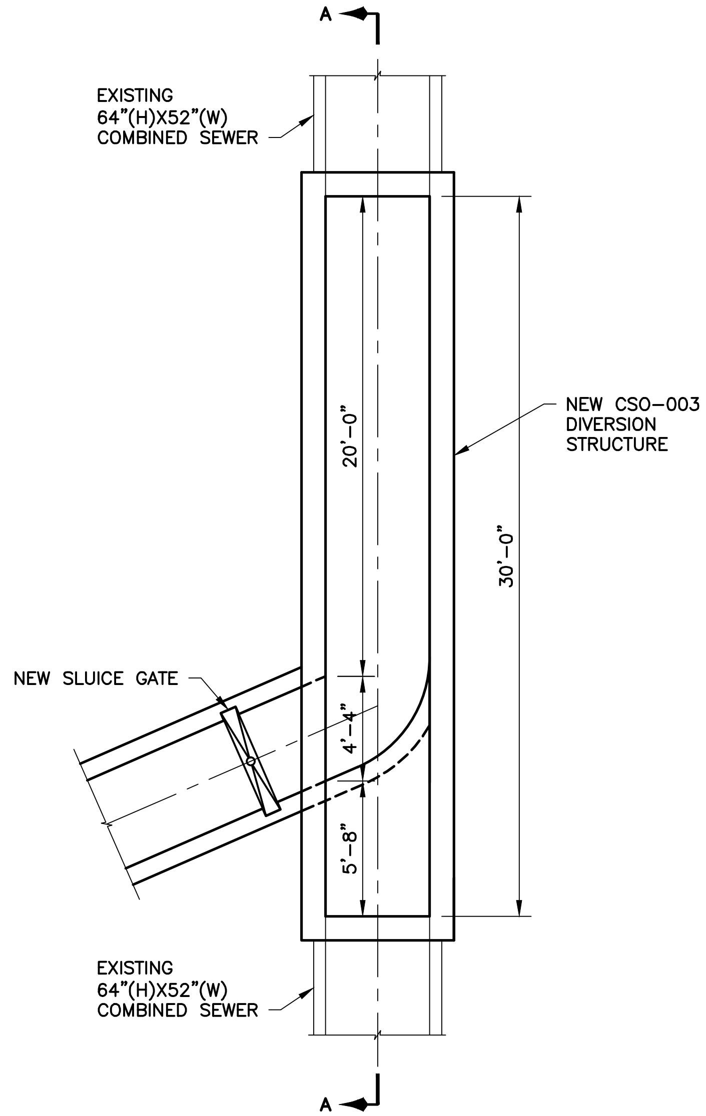
DETAIL 2/C7
DUKE ST SIPHON CHAMBER

SCALE: 1/4" = 1'-0"

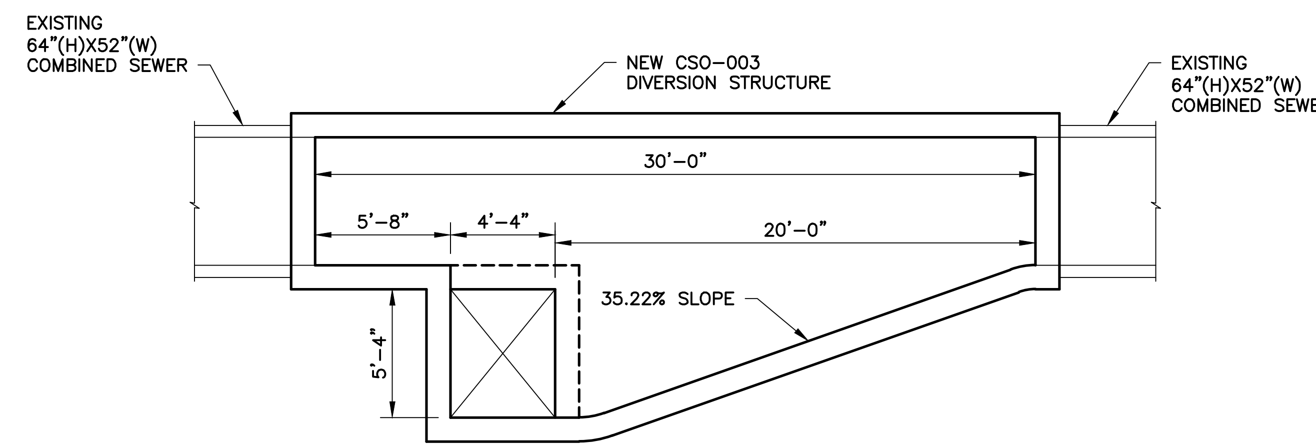
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T2
DRAWING: C7



PLAN



SECTION A

DETAIL 1/C8
CSO-003 DIVERSION STRUCTURE

NOT TO SCALE

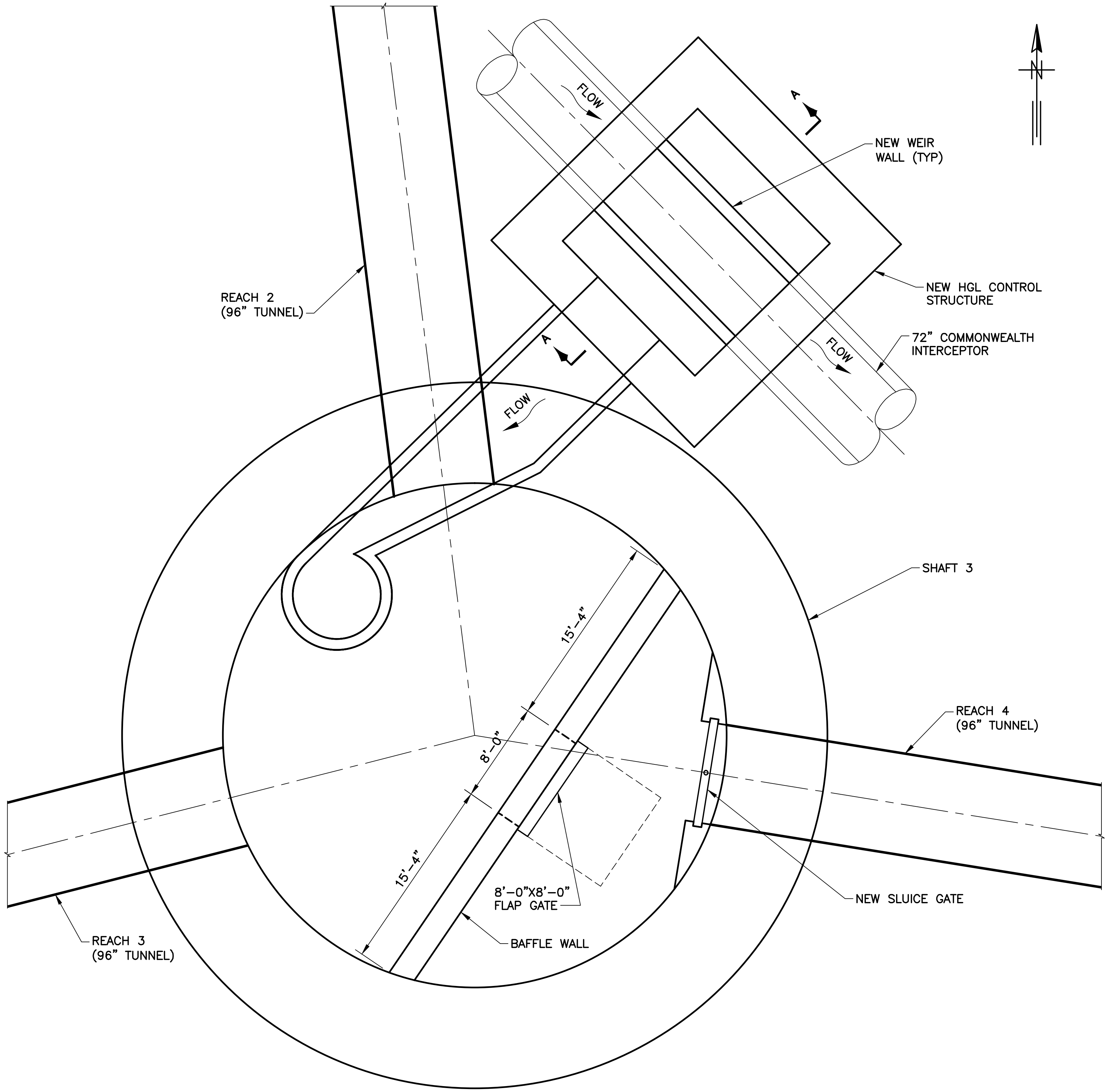
X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T2-C08.DWG 03/11/2015 2:53:54 PM

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

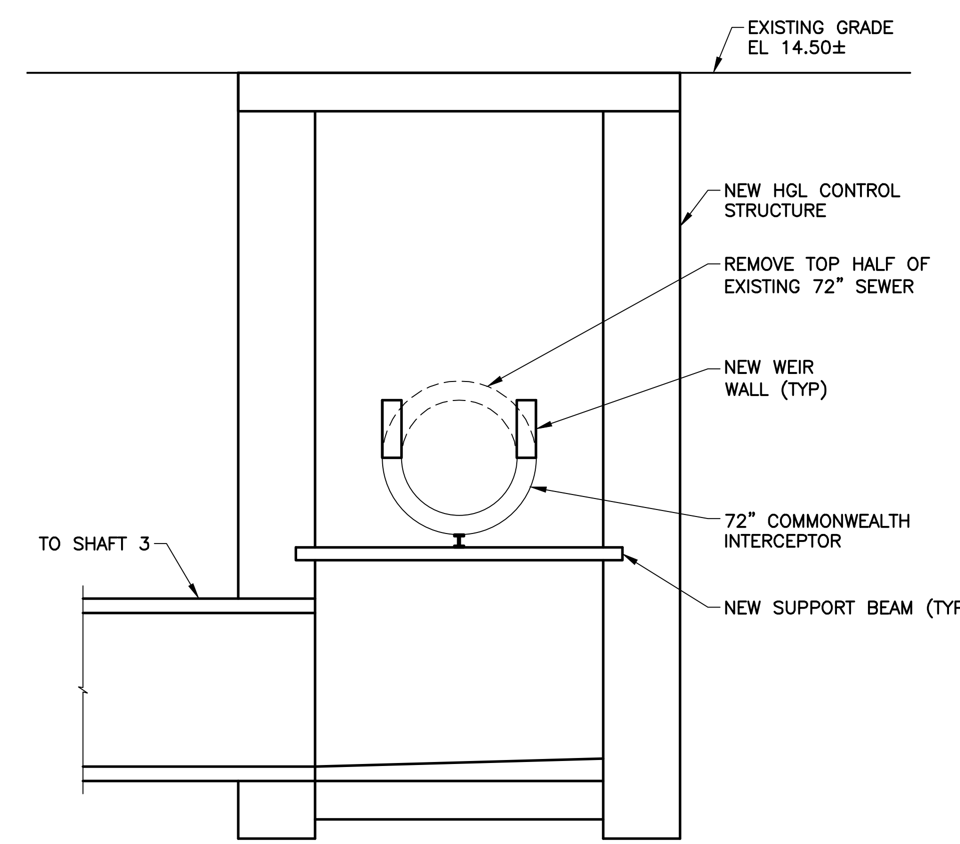
CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T2

DRAWING: C8



PLAN



SECTION A

DETAIL 1/C9
NEW HGL CONTROL STRUCTURE

SCALE: 1" = 10'

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

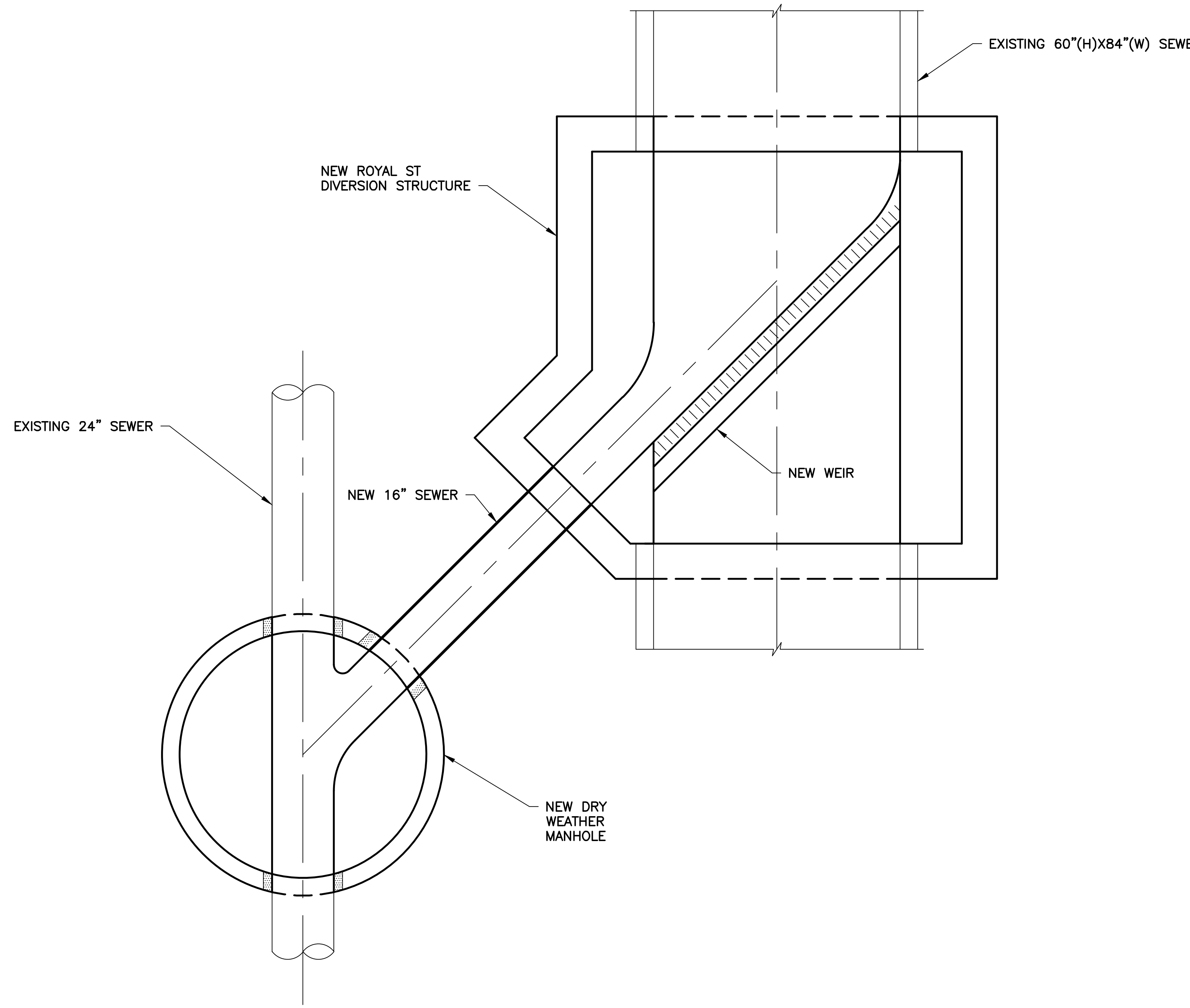
0 5 10 FT
1"=10'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T2

DRAWING: C9

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T2-C09.DWG 03/11/2015 2:54:50 PM



PLAN

DETAIL 1/C10
ROYAL ST DRY WEATHER
DIVERSION STRUCTURE
NOT TO SCALE

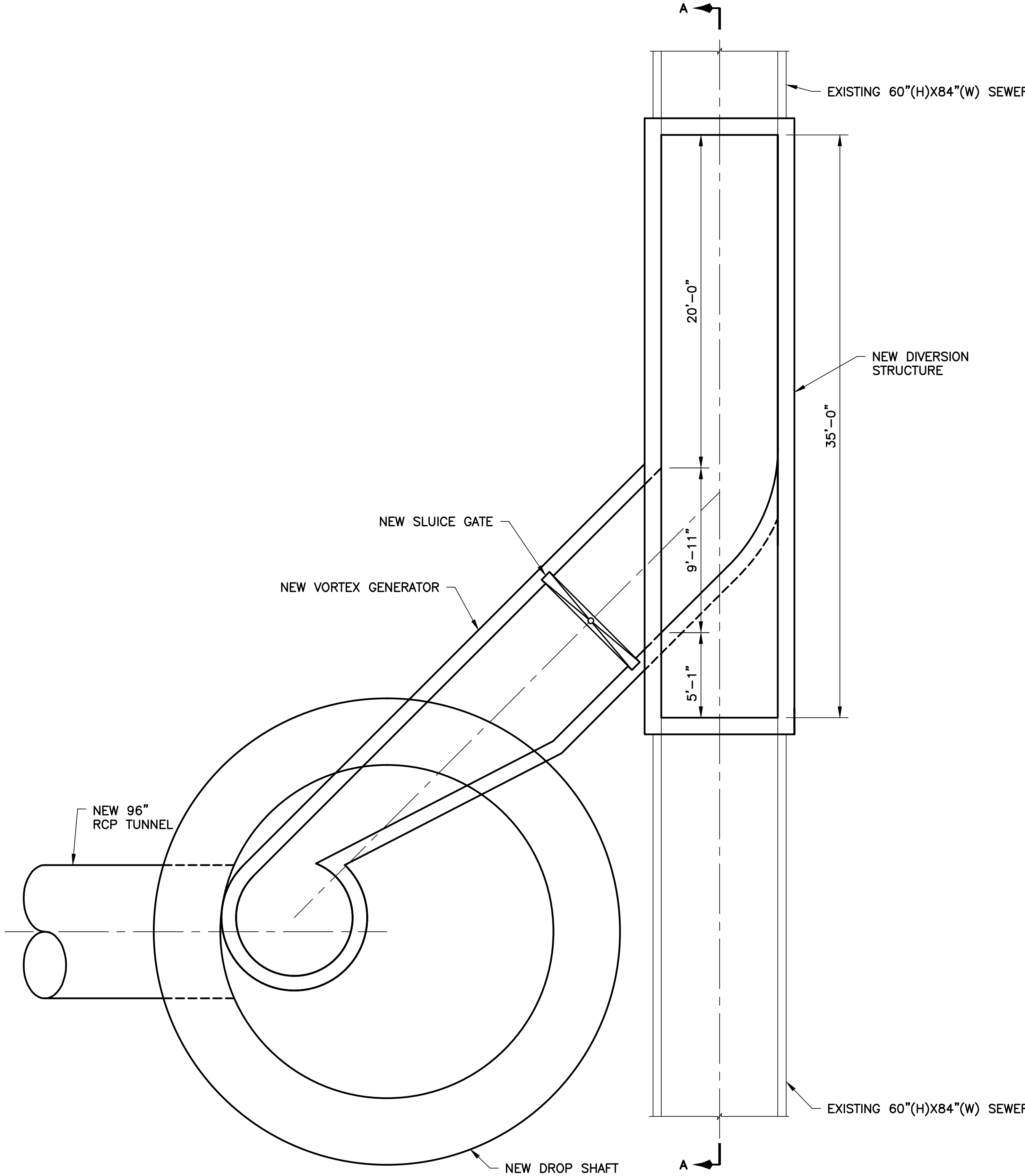
X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T2-C10.DWG 03/11/2015 3:09:08 PM

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

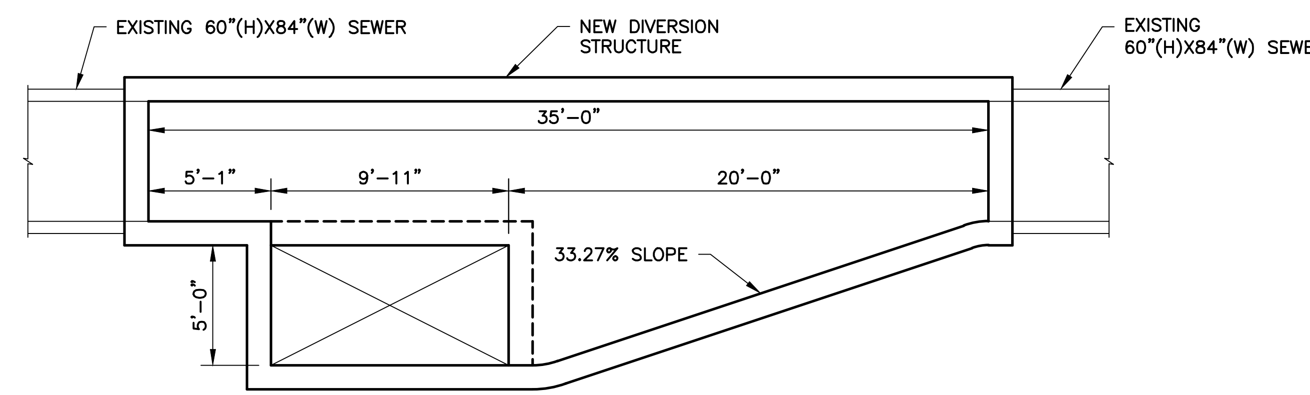
CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T2

DRAWING: C10



PLAN



SECTION A

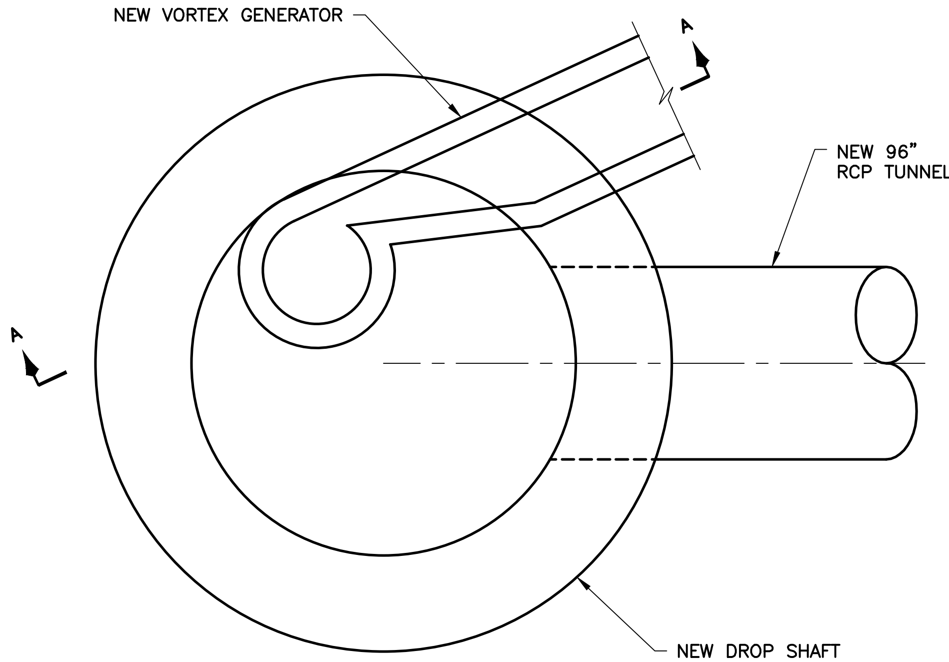
DETAIL 1/C11
CSO-002 VORTEX GENERATOR AND DIVERSION STRUCTURE
NOT TO SCALE

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

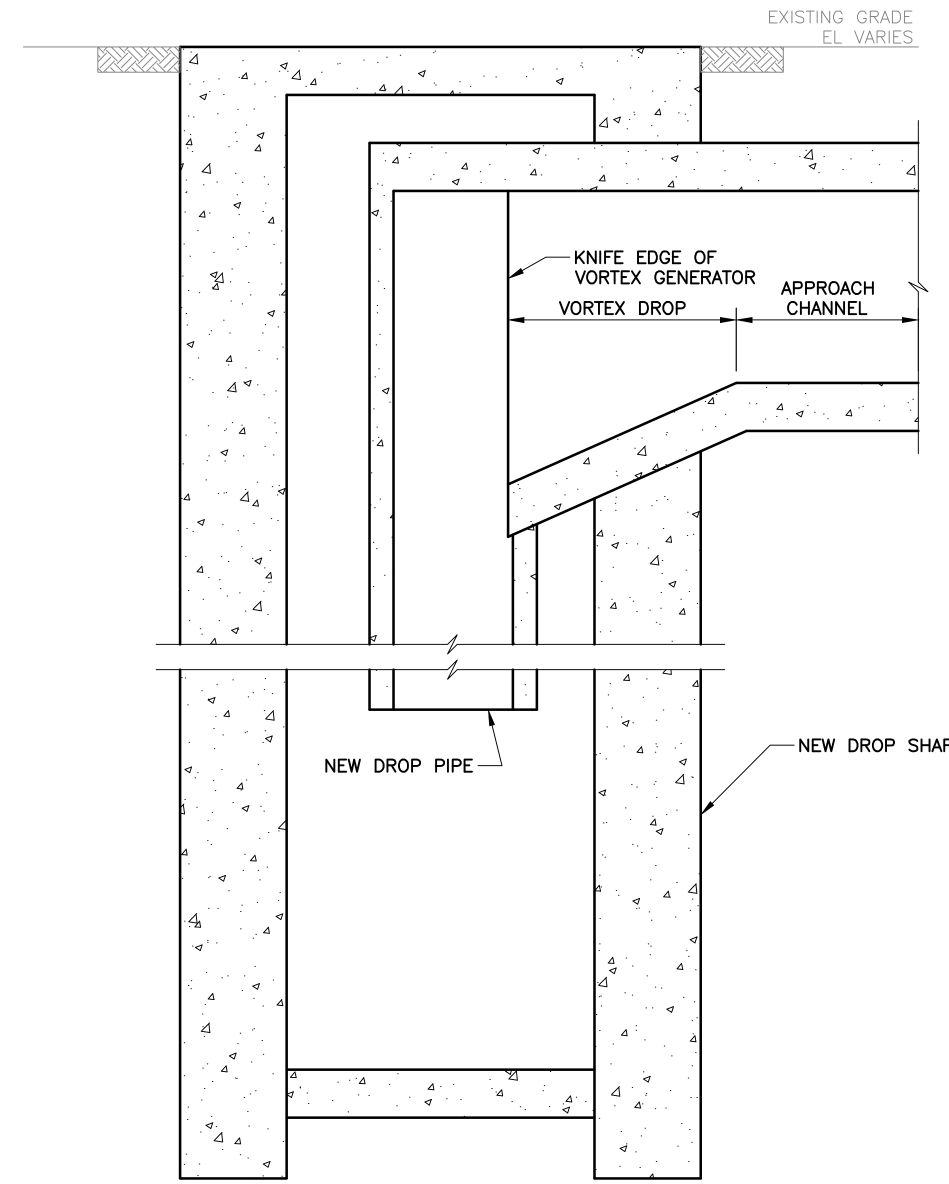
CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T2
DRAWING: C11

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T2-C11.DWG 03/11/2015 3:10:05 PM



PLAN



SECTION A

DETAIL 1/C12
TYPICAL DROP SHAFT AND
VORTEX GENERATOR
NOT TO SCALE

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T2-C12.DWG 03/11/2015 2:57:10 PM

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

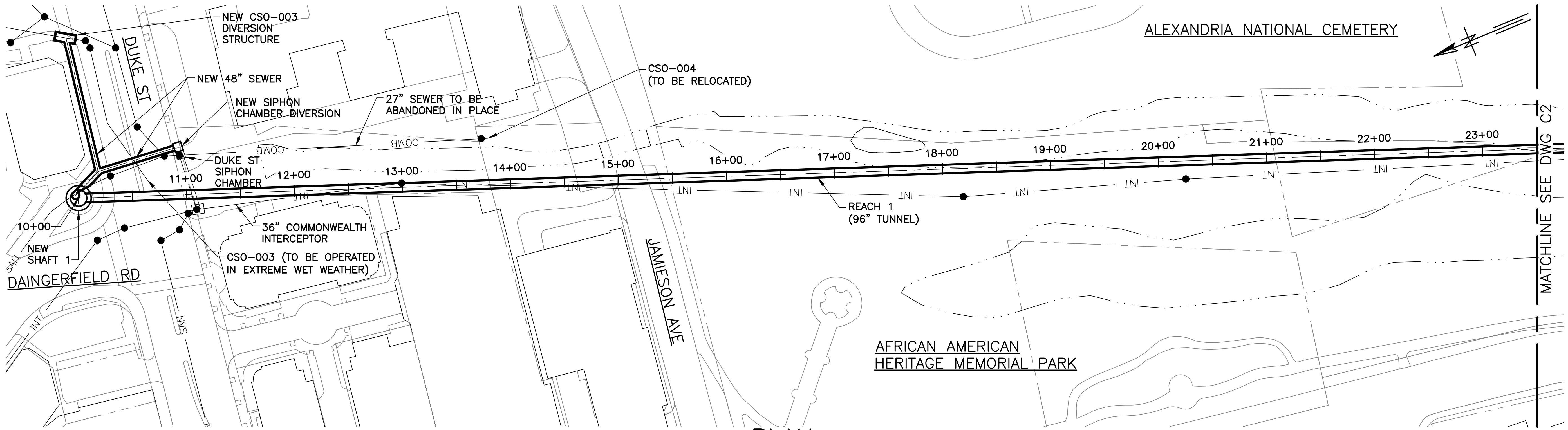
CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T2

DRAWING: C12

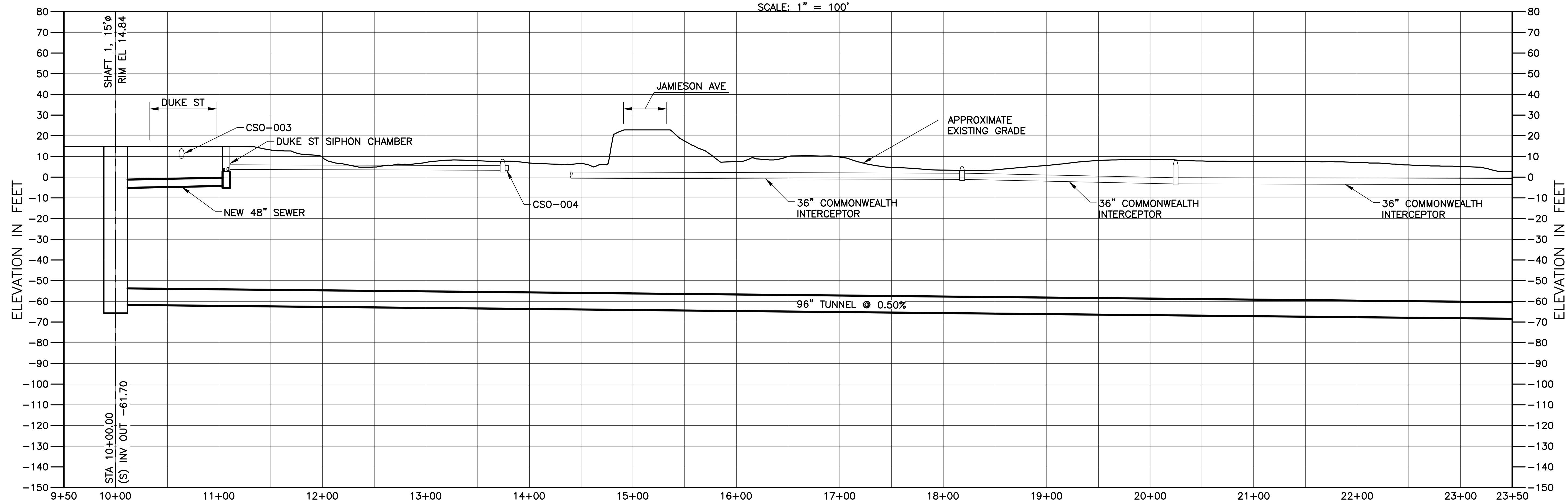
Attachment D

CSO-003/004 Tunnel and CSO-002 Tunnel to the Potomac River (Alternative T3)



PLAN

SCALE: 1" = 100'



STATION

PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T3-C01.DWG 04/08/2015 10:38:30 AM

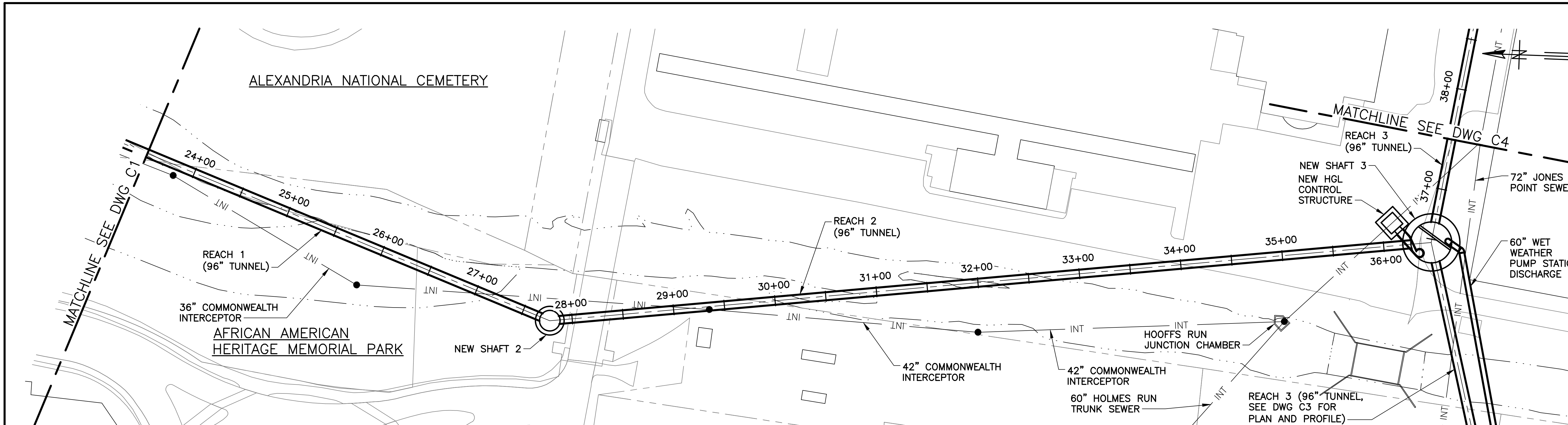
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'
0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

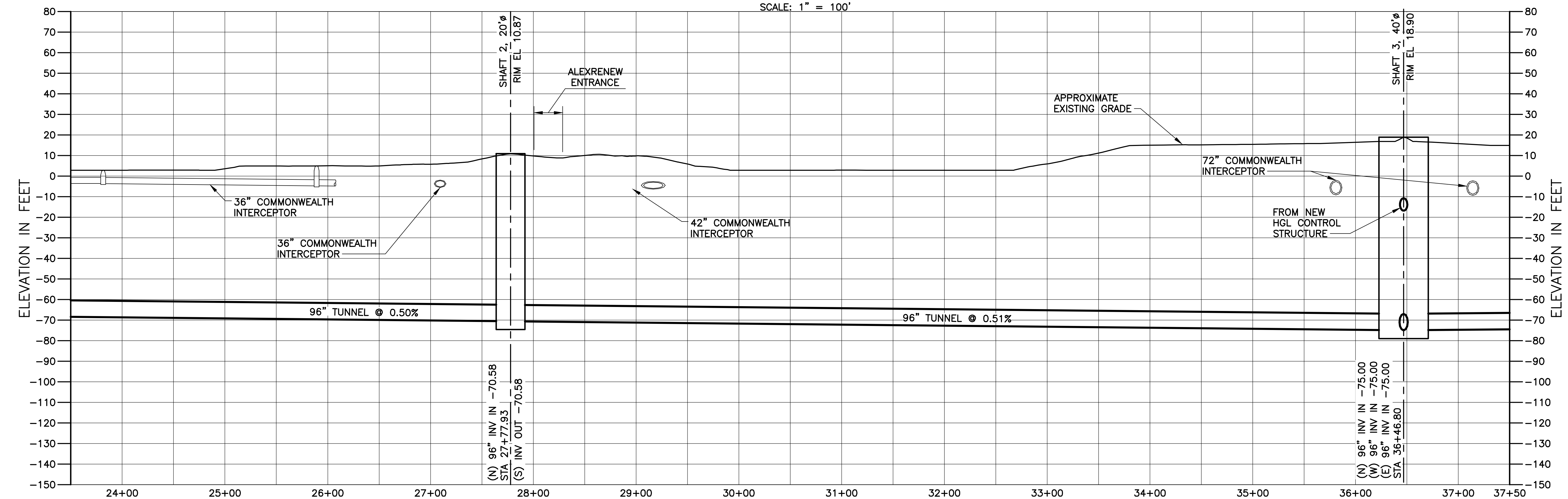
TUNNEL CONFIGURATION ALTERNATIVE T3

DRAWING: C1



PLAN

SCALE: 1" = 100'



PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T3-C02.DWG 03/11/2015 3:44:44 PM

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

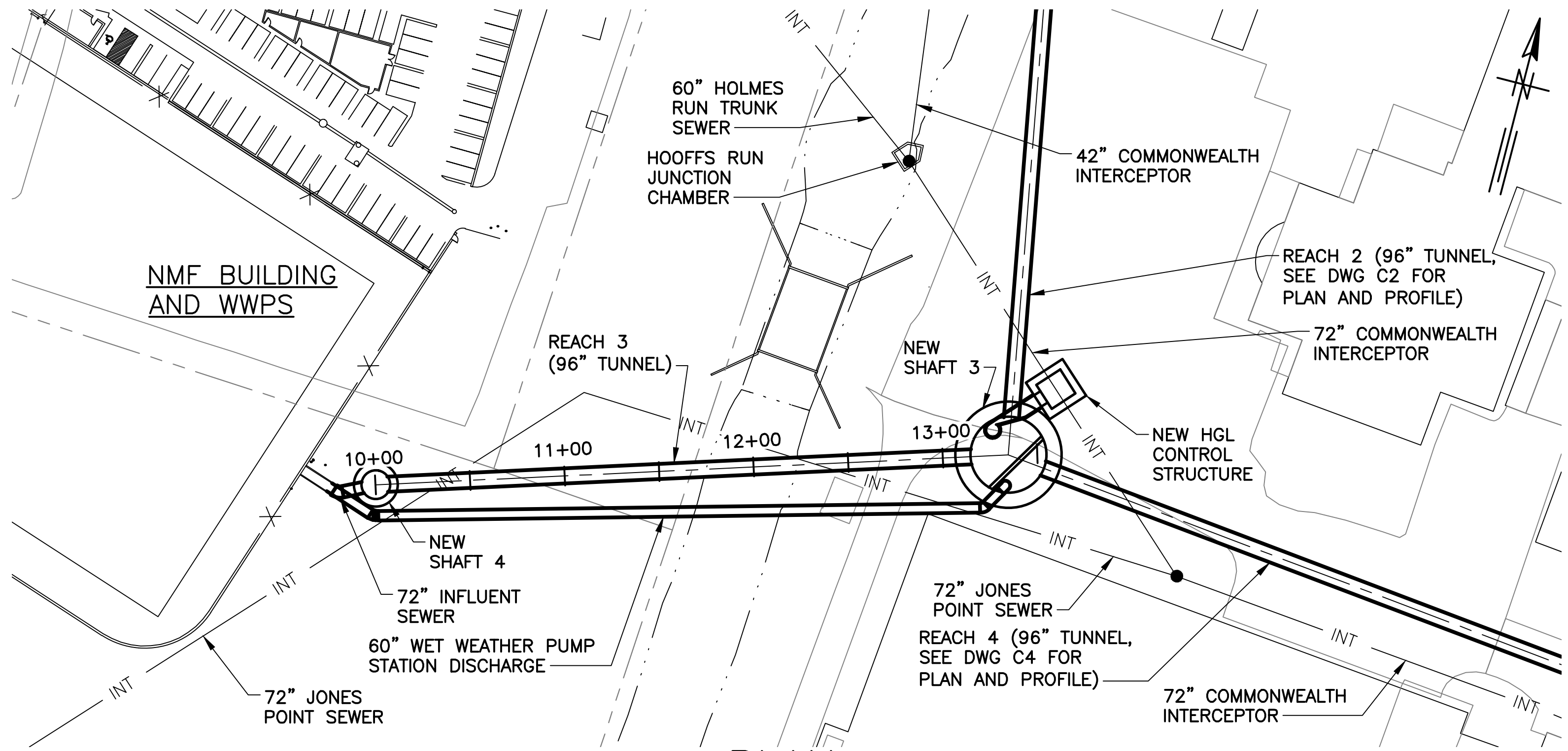
0 50 100 FT 1"=100'

0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

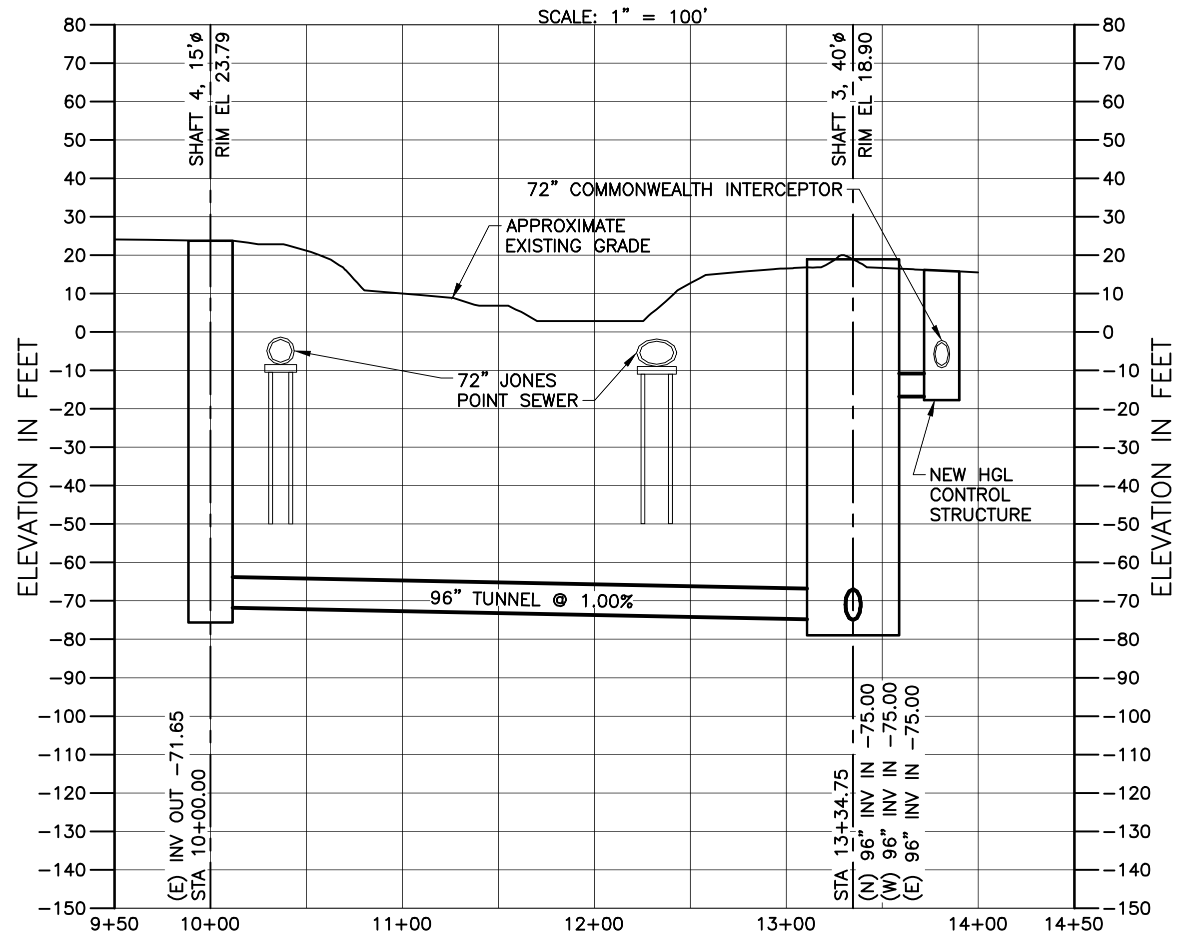
TUNNEL CONFIGURATION ALTERNATIVE T3

DRAWING: C2



PLAN

SCALE: 1" = 100'



PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T3-C03.DWG 03/11/2015 4:18:22 PM

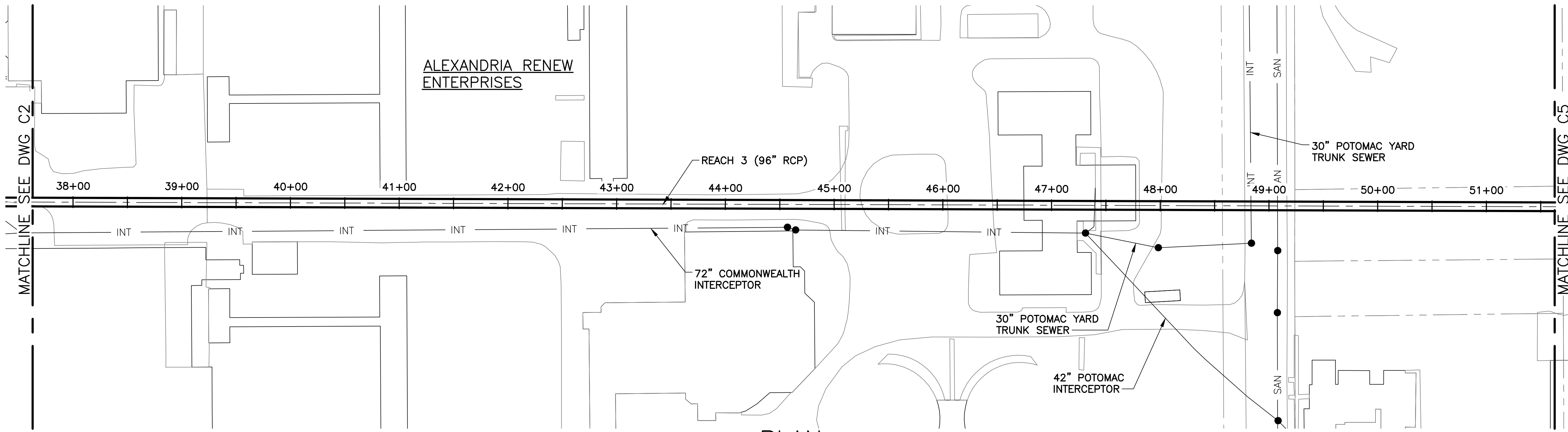
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'
0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

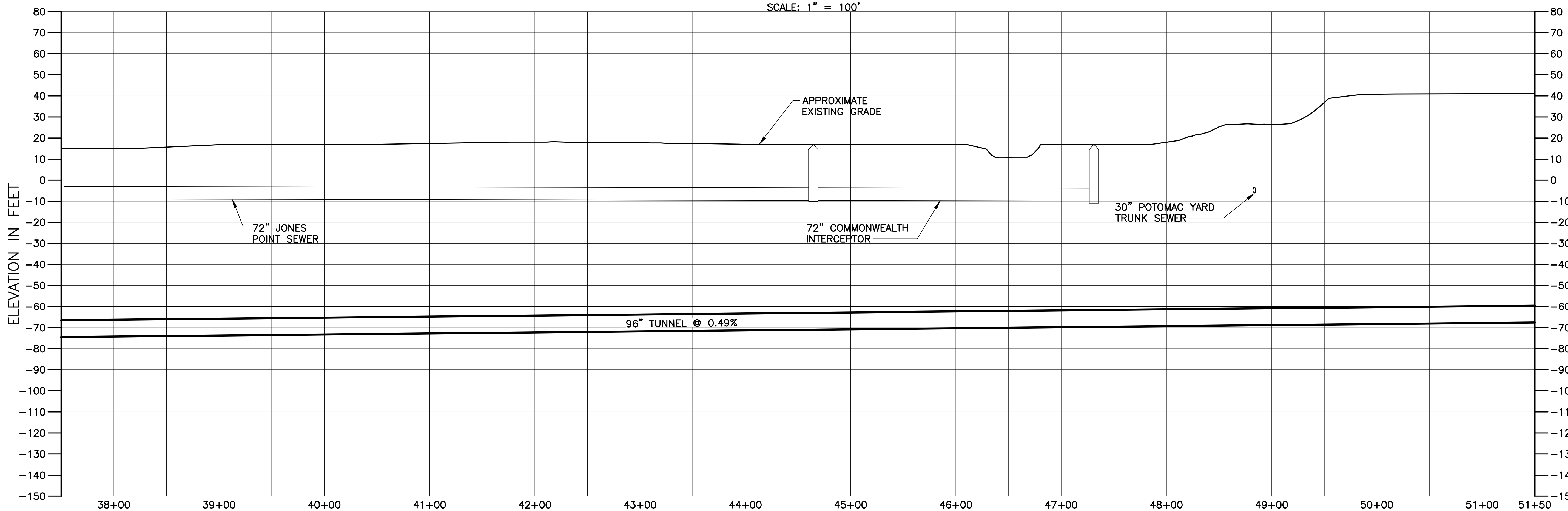
TUNNEL CONFIGURATION ALTERNATIVE T3

DRAWING: C3



PLAN

SCALE: 1" = 100'



STATION

PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T3-C04.DWG 03/11/2015 4:01:25 PM

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

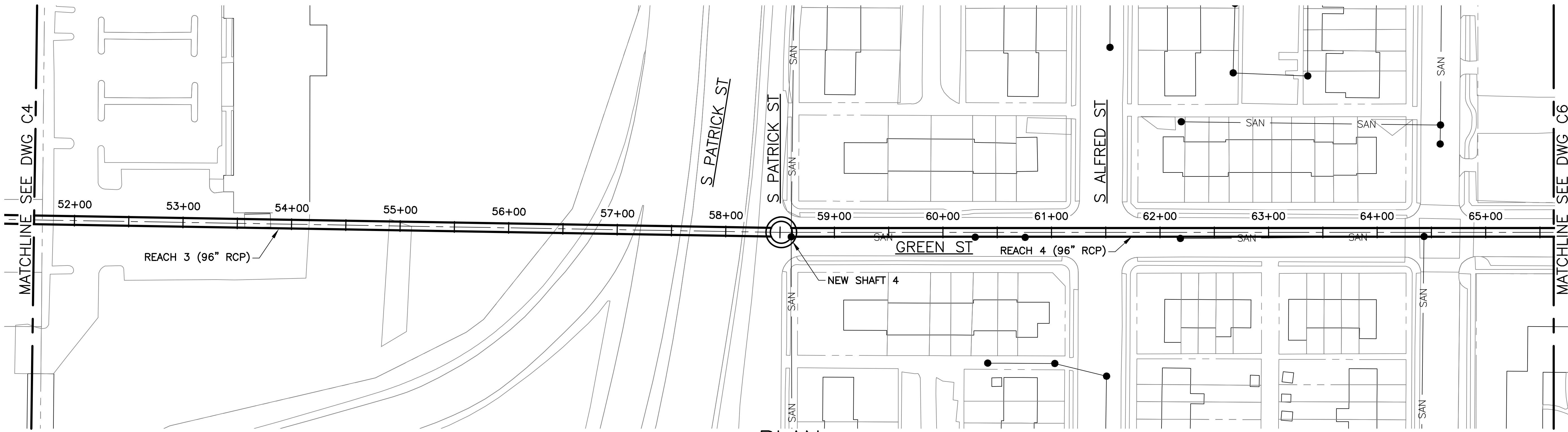
0 50 100 FT
1"=100'

0 50 FT
1"=50'

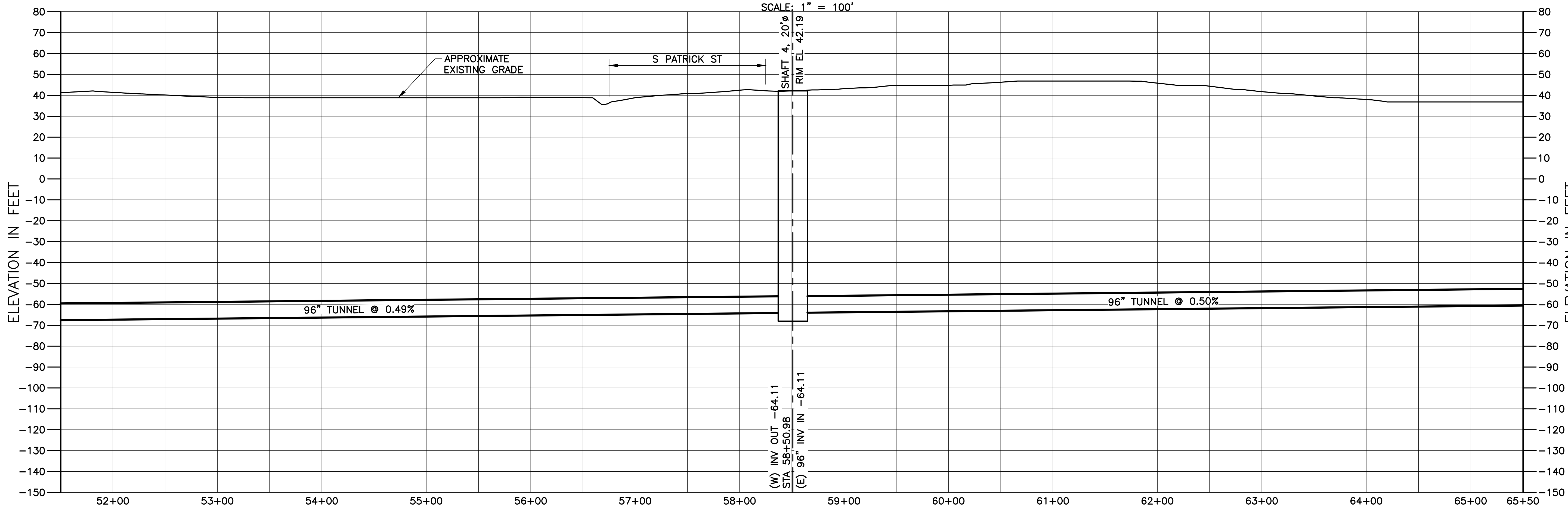
CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T3

DRAWING: C4



PLAN
SCALE: 1" = 100'



STATION
PROFILE
SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

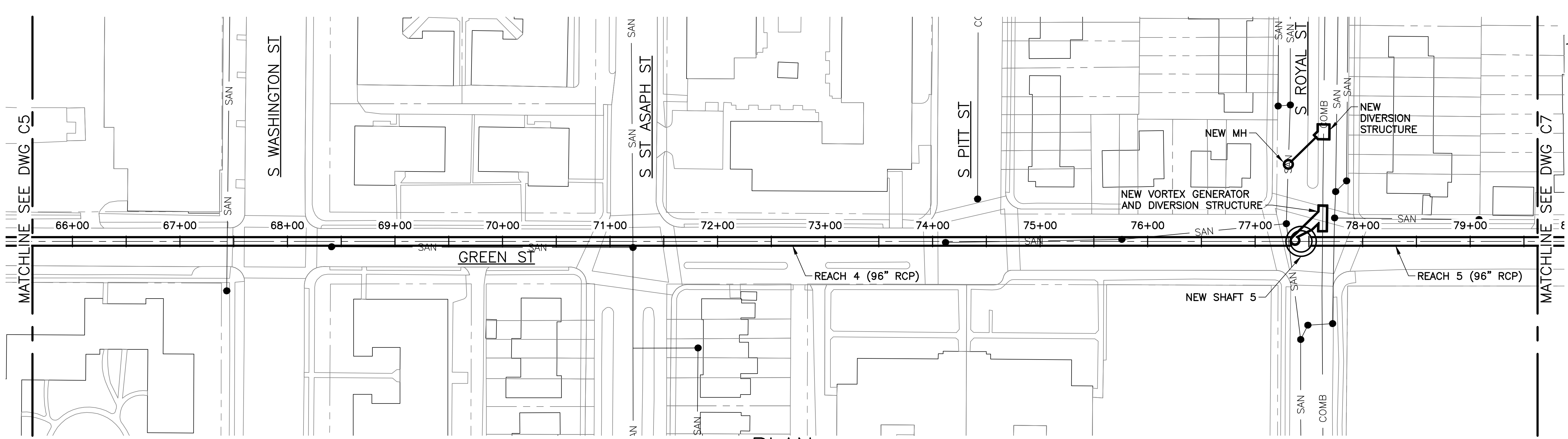
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'
0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

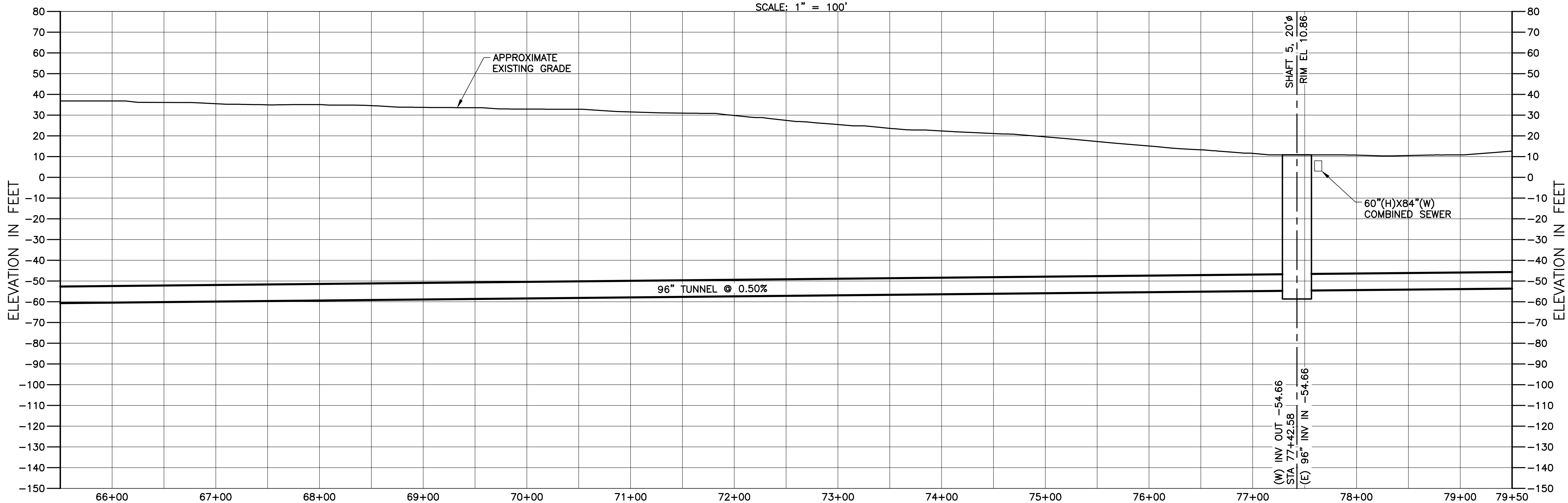
TUNNEL CONFIGURATION ALTERNATIVE T3
DRAWING: C5

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T3-C05.DWG 03/11/2015 4:03:28 PM



PLAN

SCALE: 1" = 100'



STATION

PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'

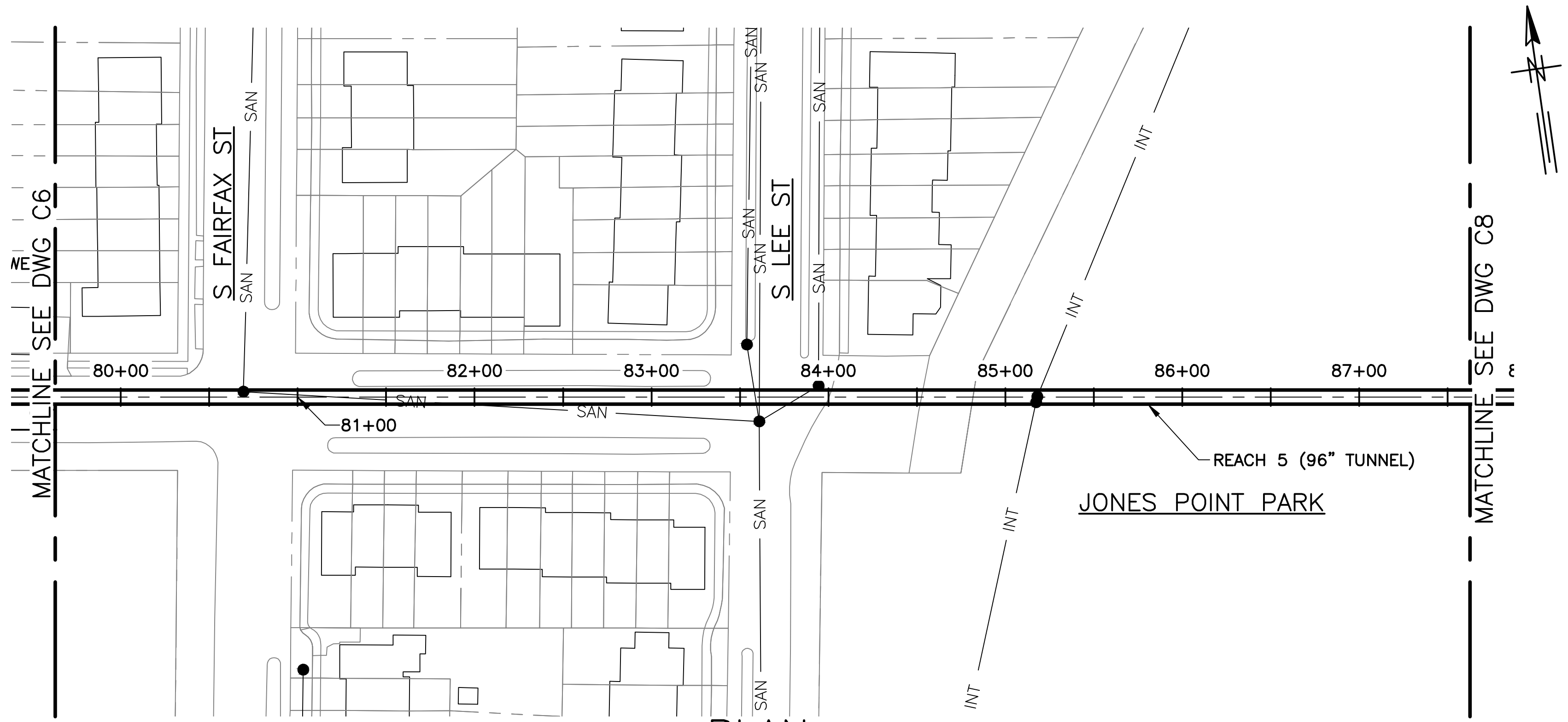
0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T3

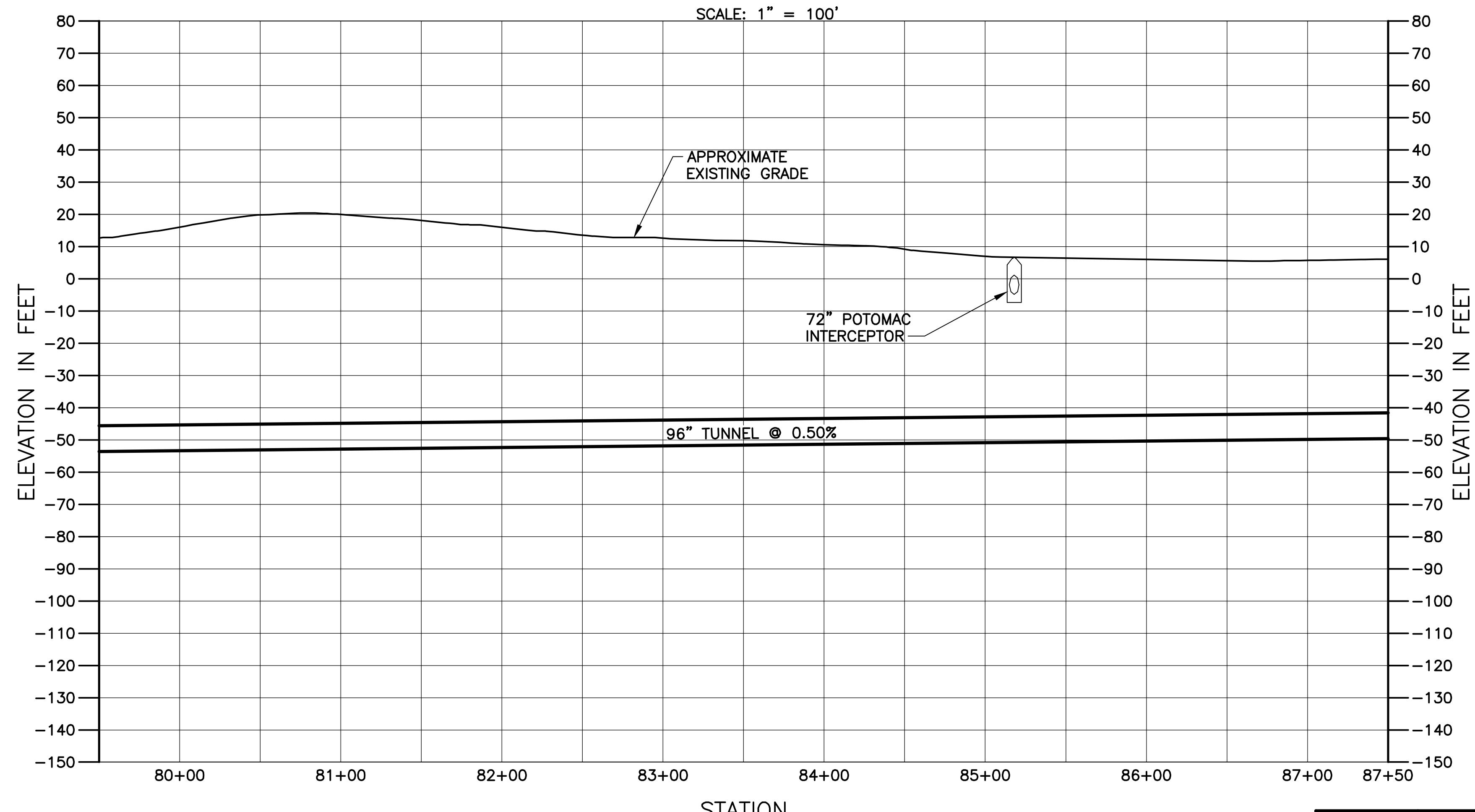
DRAWING: C6

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T3-C06.DWG 03/11/2015 4:06:09 PM



PLAN

SCALE: 1" = 100'



PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T3-C07.DWG 03/11/2015 4:07:48 PM

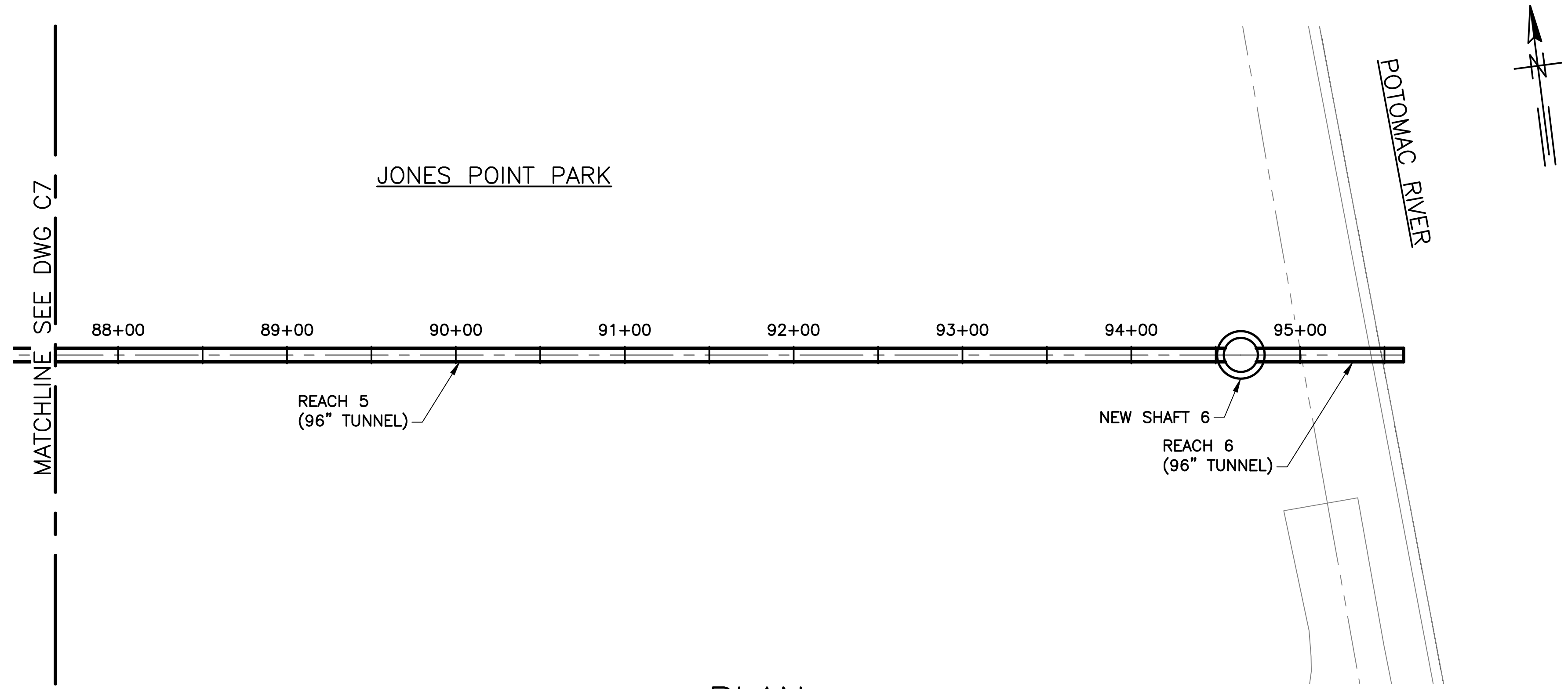
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'
0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

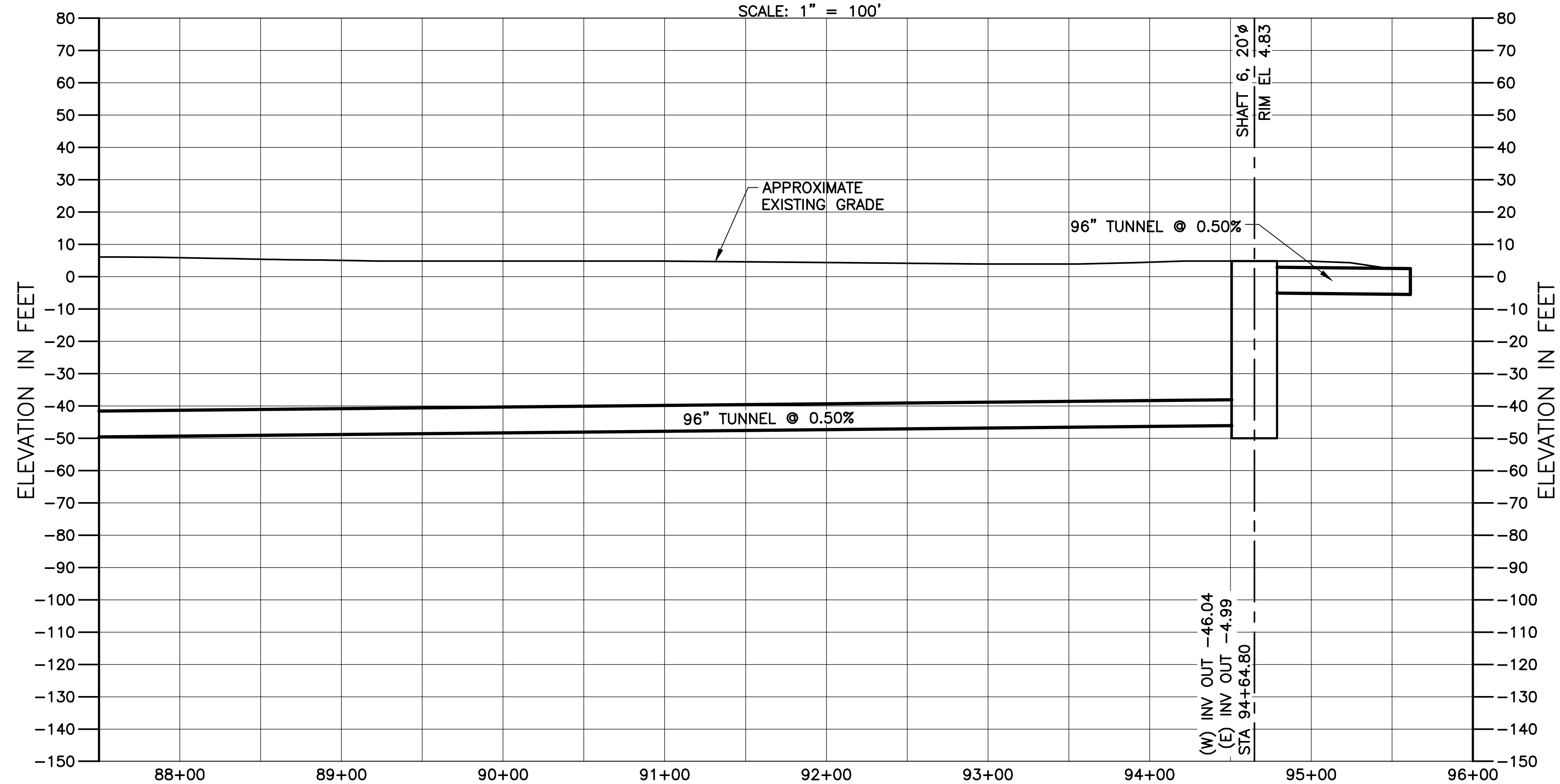
TUNNEL CONFIGURATION ALTERNATIVE T3

DRAWING: C7



PLAN

SCALE: 1" = 100'



PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

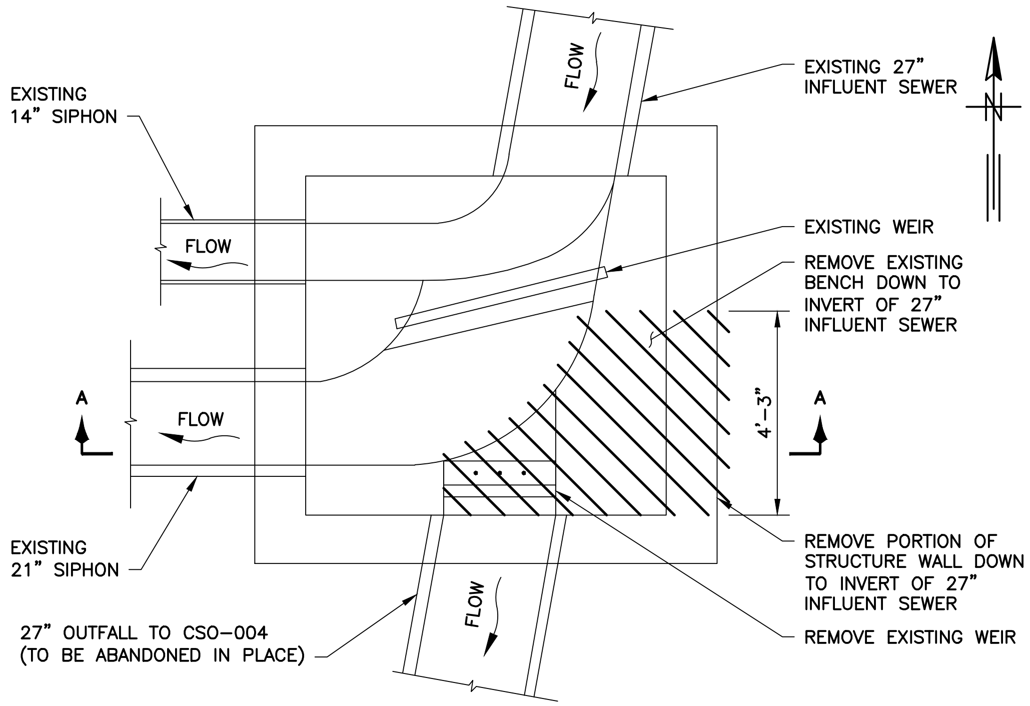
0 50 100 FT 1"=100'
0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

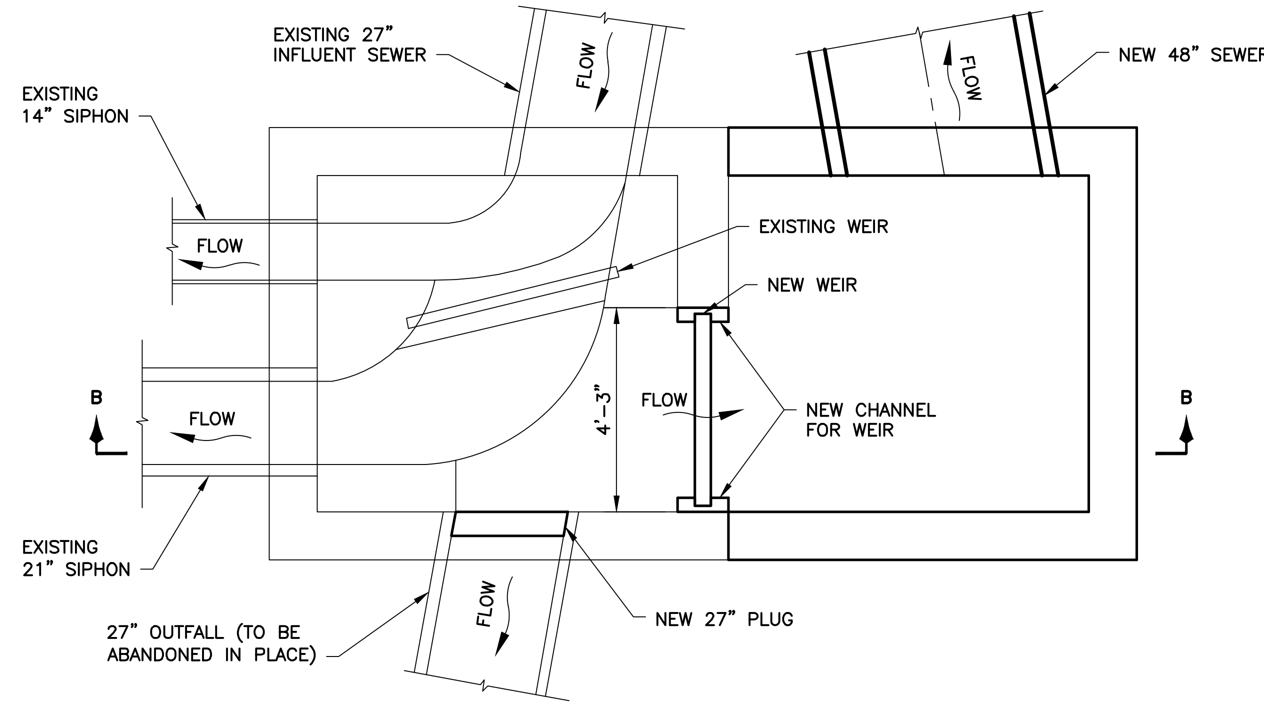
TUNNEL CONFIGURATION ALTERNATIVE T3

DRAWING: C8

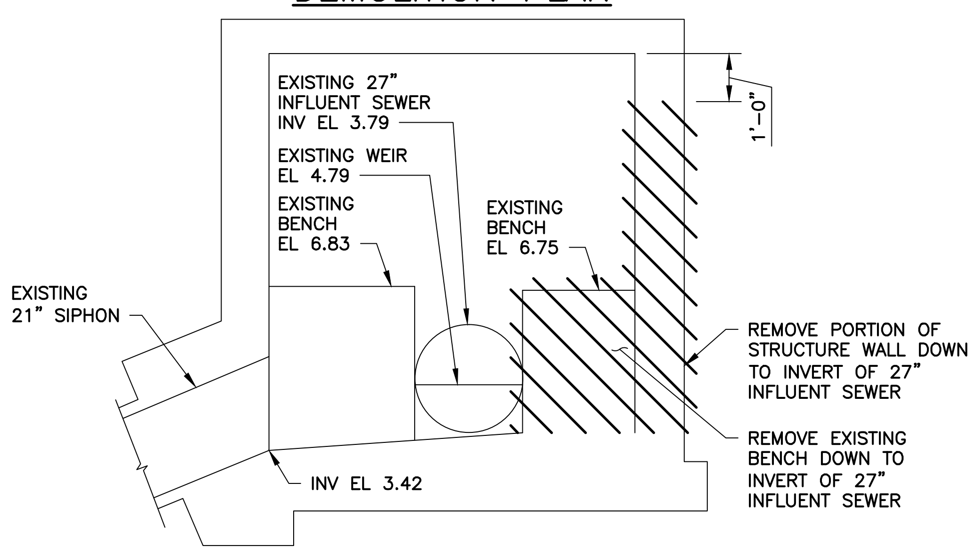
X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T3-C08.DWG 03/11/2015 4:12:28 PM



DEMOLITION PLAN

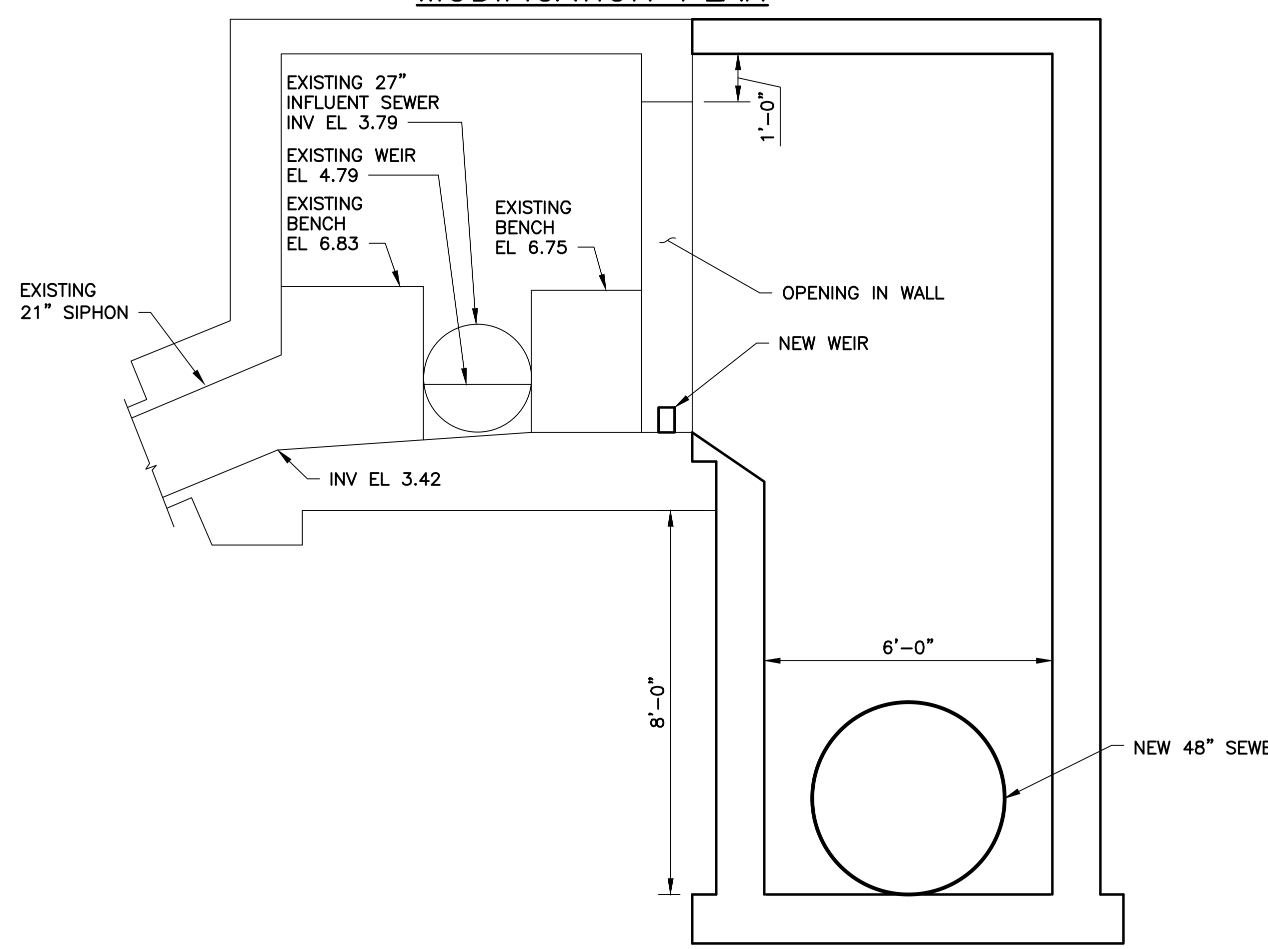


MODIFICATION PLAN



SECTION A – DEMOLITION

DETAIL 1/C9
DUKE ST SIPHON CHAMBER
SCALE: 1/4" = 1'-0"



SECTION B – MODIFICATION

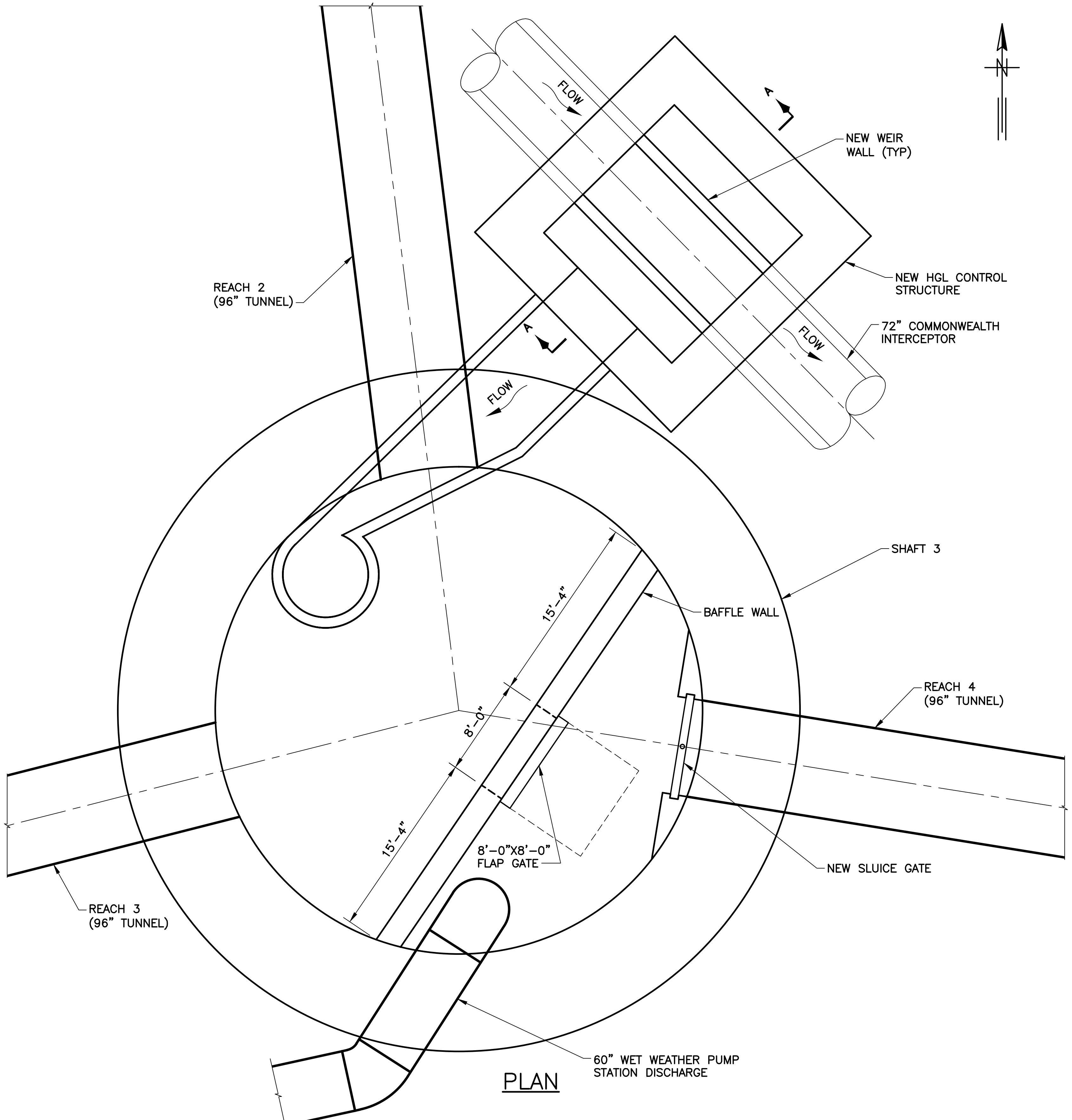
DETAIL 2/C9
DUKE ST SIPHON CHAMBER
SCALE: 1/4" = 1'-0"

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

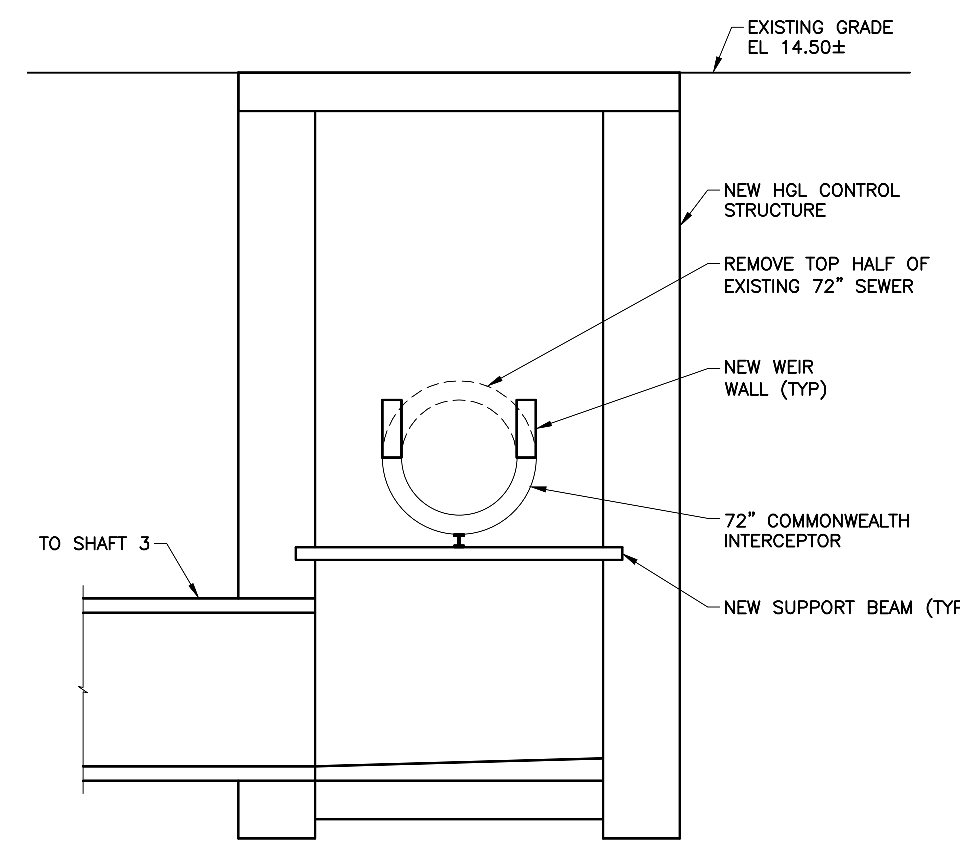
CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T3
DRAWING: C9

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T3-C09.DWG 03/11/2015 3:23:25 PM



PLAN



SECTION A

DETAIL 1/C10
NEW HGL CONTROL STRUCTURE
SCALE: 1" = 10'

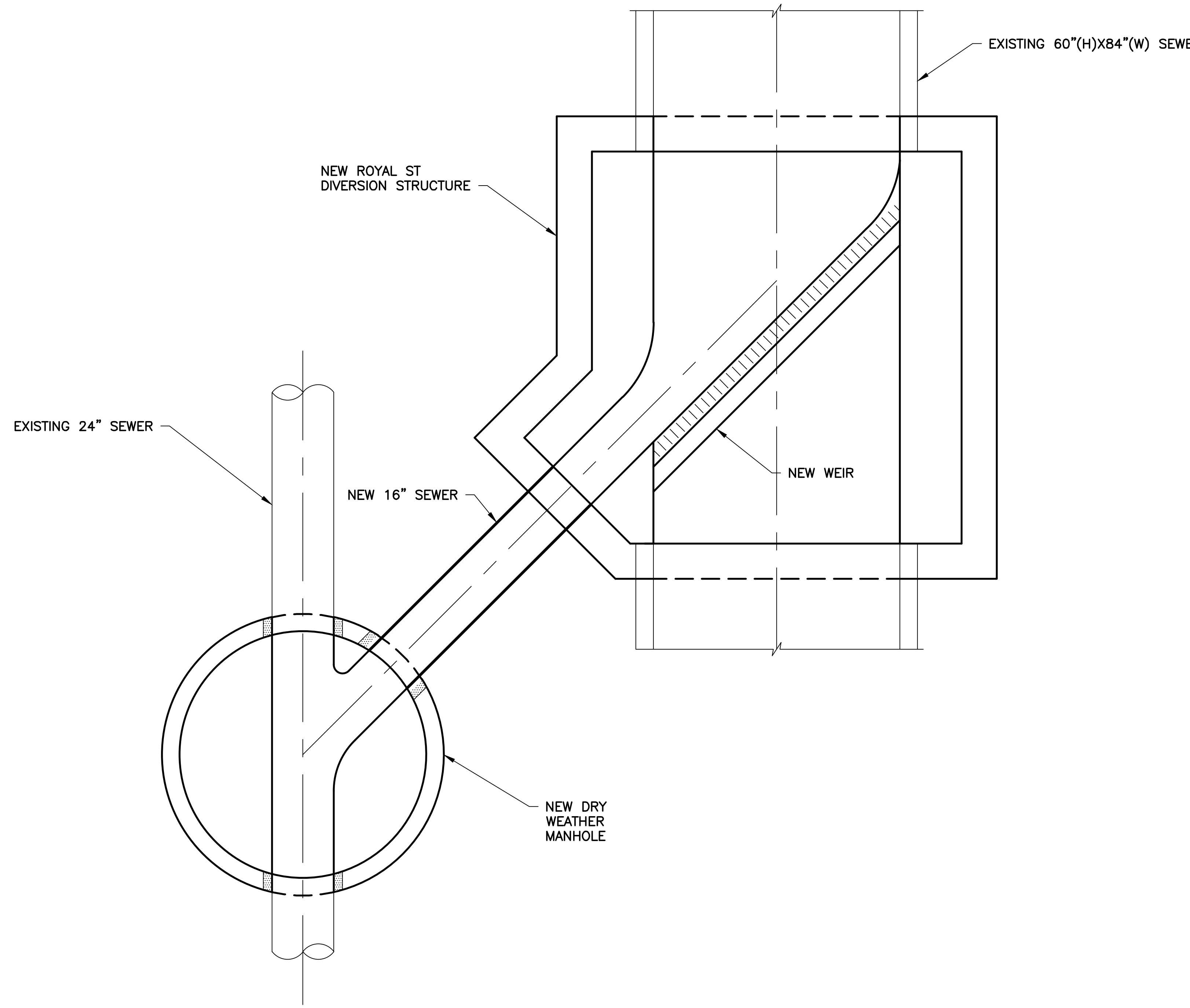
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 5 10 FT
1"=10'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T3
DRAWING: C10

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T3-C10.DWG 03/11/2015 4:19:30 PM



PLAN

DETAIL 1/C11
ROYAL ST DRY WEATHER
DIVERSION STRUCTURE
NOT TO SCALE

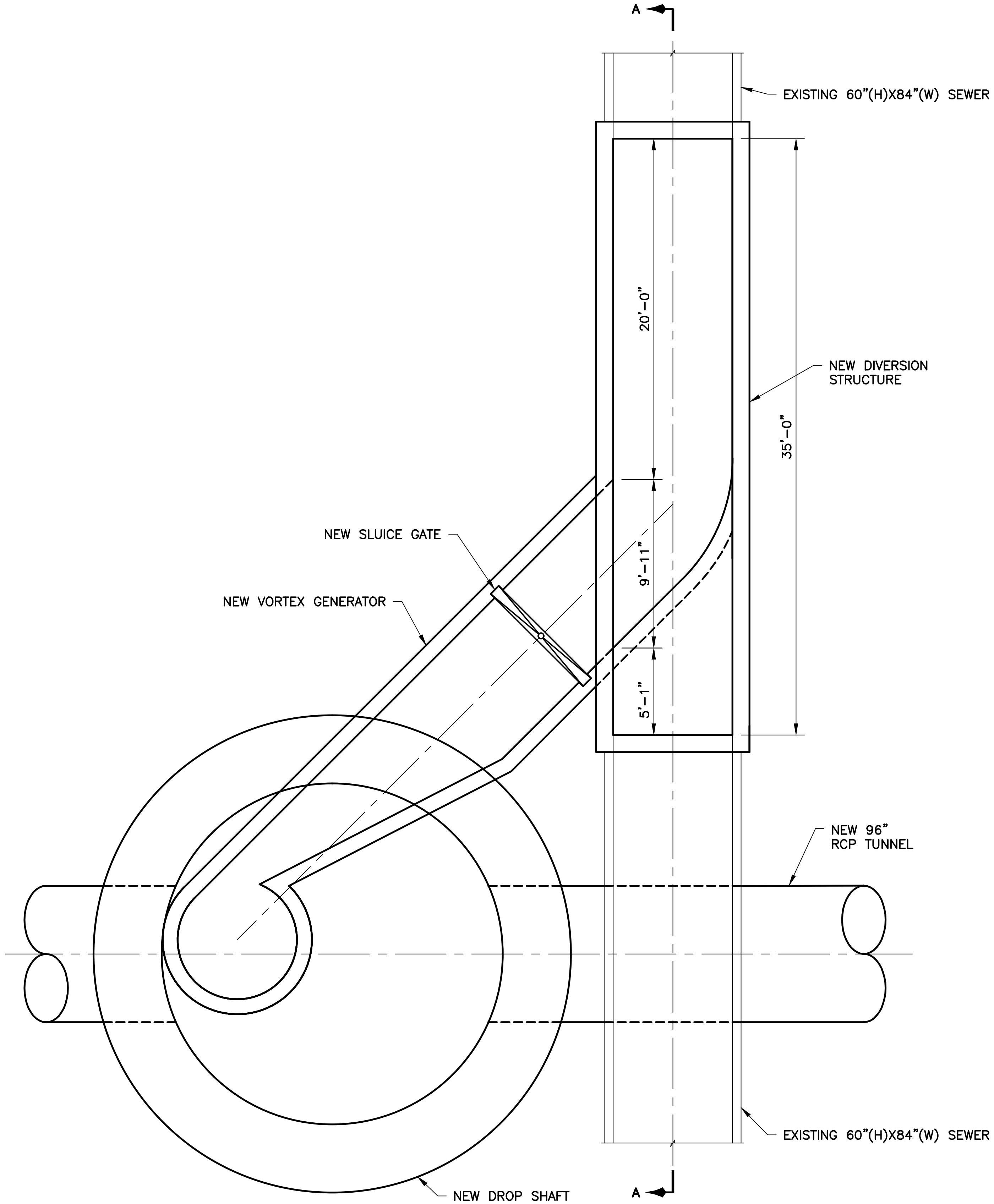
X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T3-C11.DWG 03/11/2015 3:15:41 PM

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

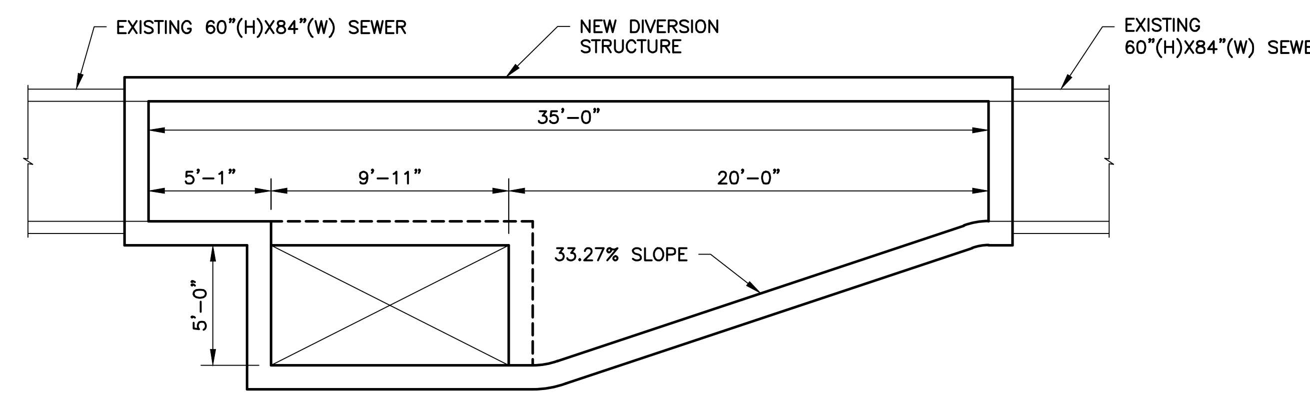
CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T3

DRAWING: C11



PLAN



SECTION A

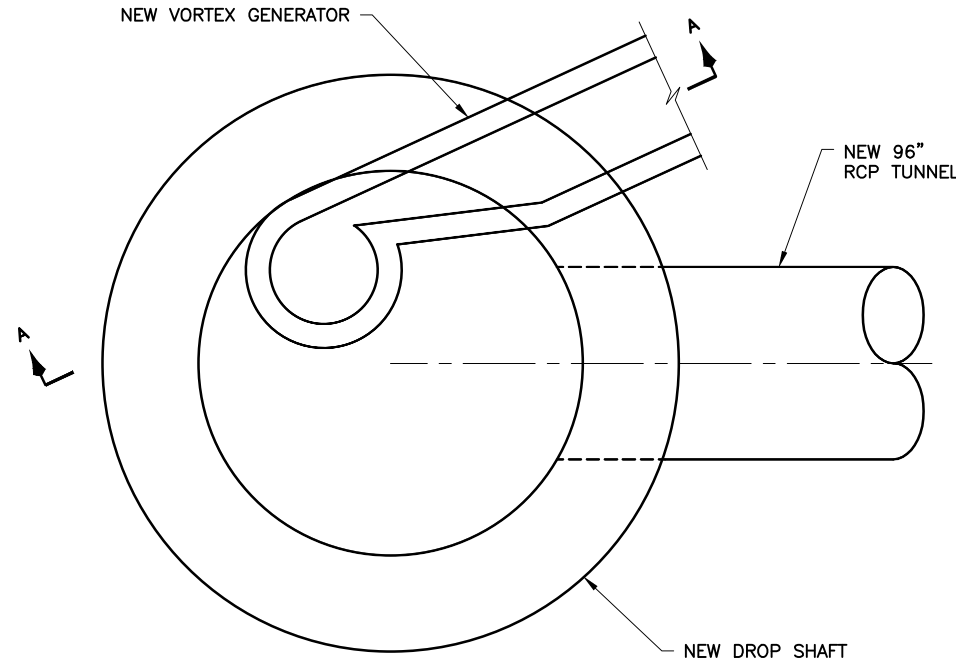
DETAIL 1/C12
CSO-002 VORTEX GENERATOR
AND DIVERSION STRUCTURE
NOT TO SCALE

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

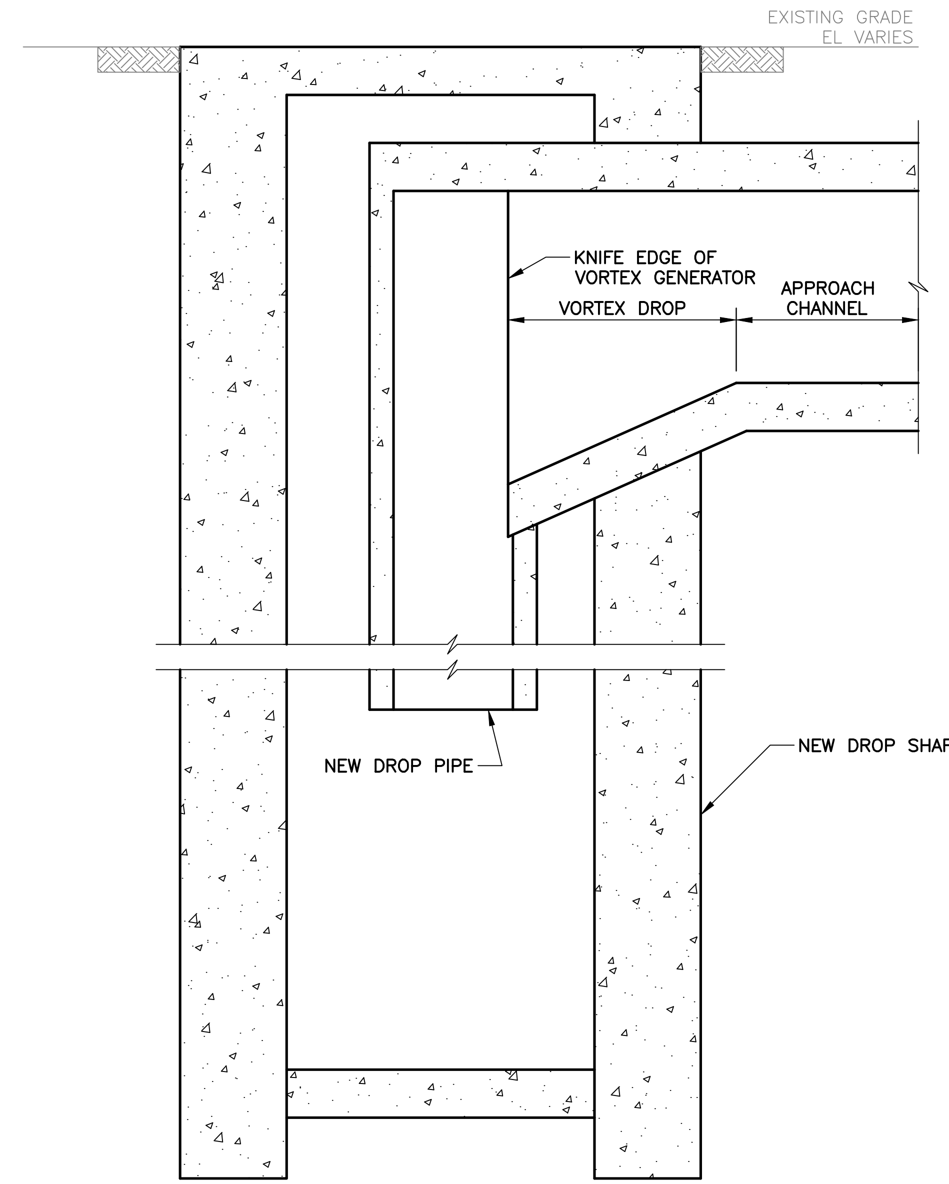
CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T3

DRAWING: C12



PLAN



SECTION A

DETAIL 1/C13
TYPICAL DROP SHAFT AND
VORTEX GENERATOR
NOT TO SCALE

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T3-C13.DWG 03/11/2015 3:16:59 PM

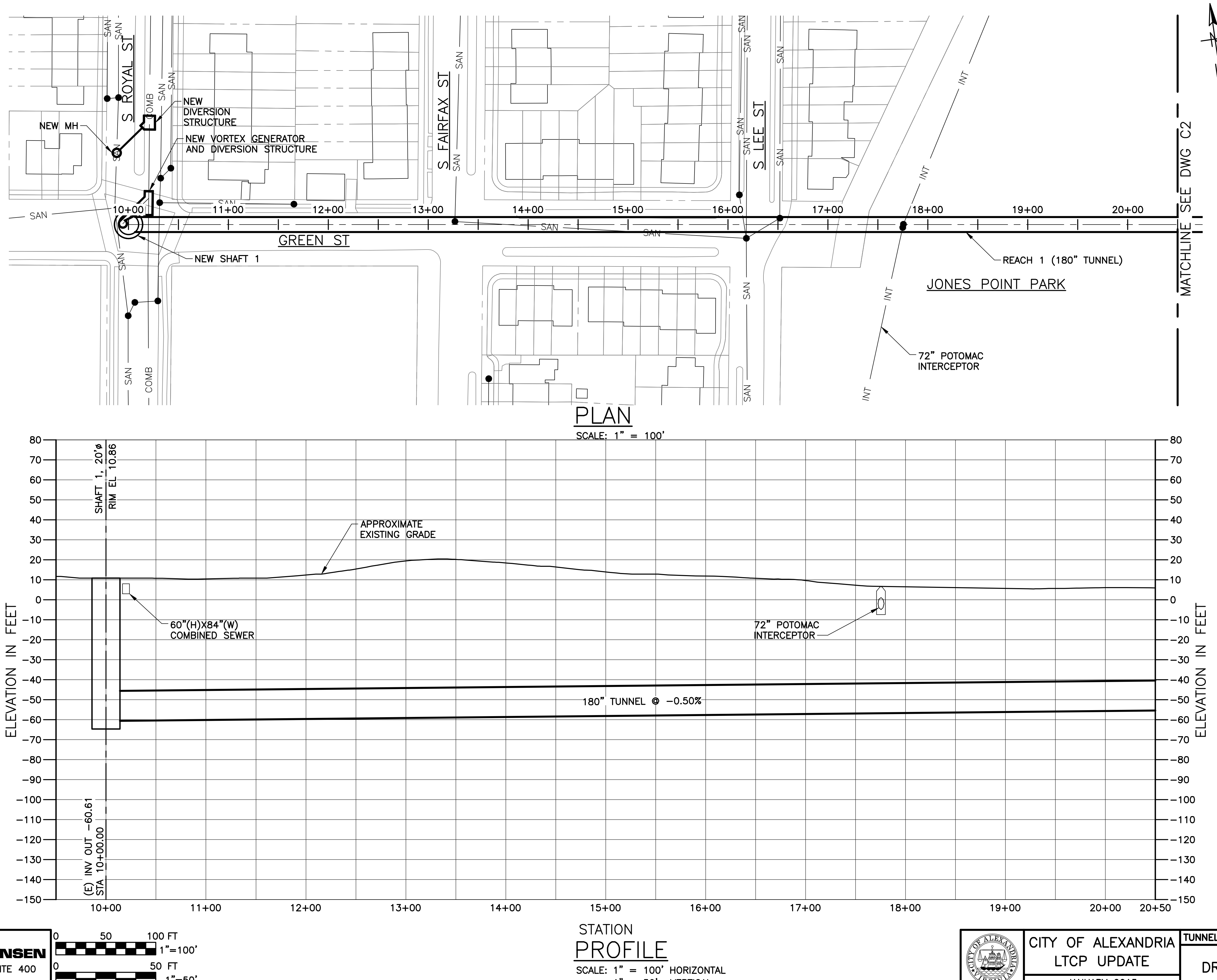
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T3
DRAWING: C13

Attachment E

CSO-002 Tunnel to the Potomac River (Alternative T4)



X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T4-C01.DWG 03/09/2015 10:32:23 AM

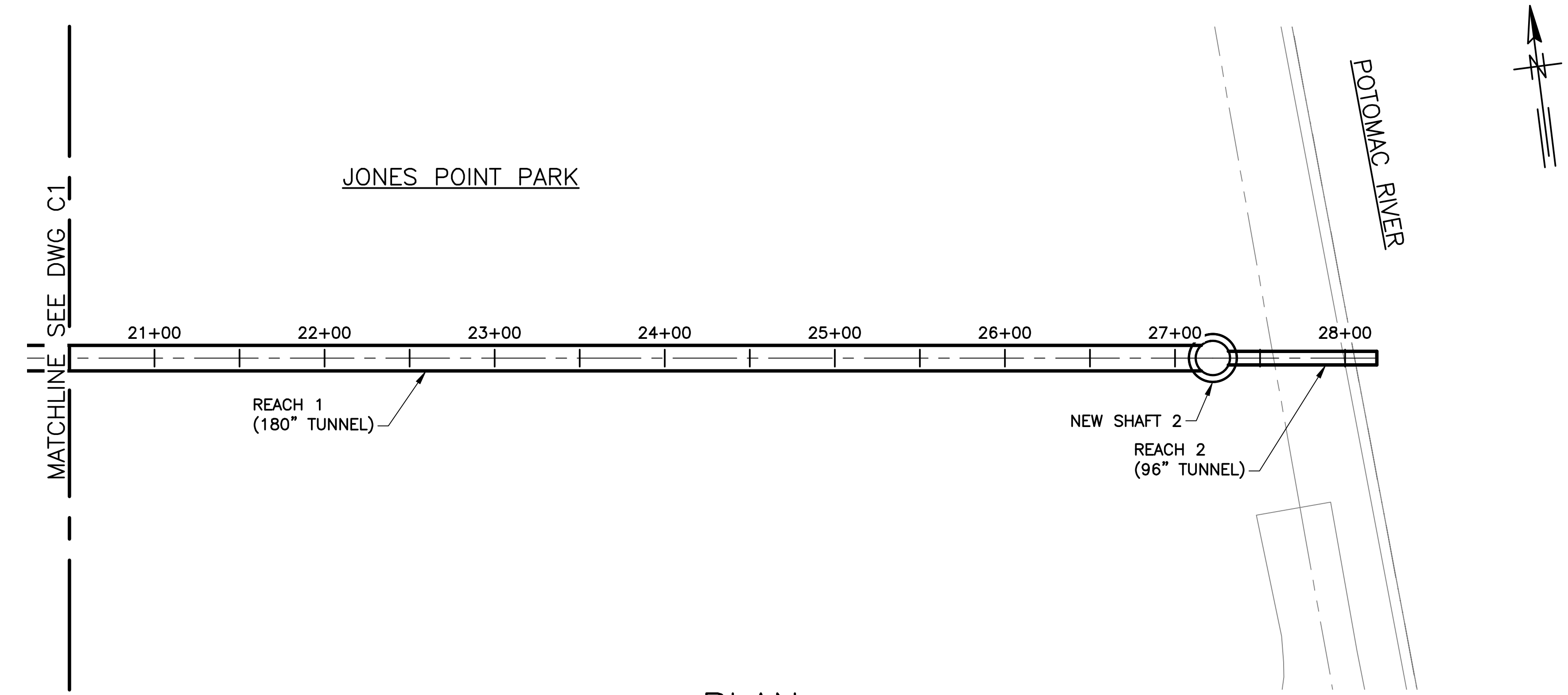
GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT
1"=100'
0 50 FT
1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

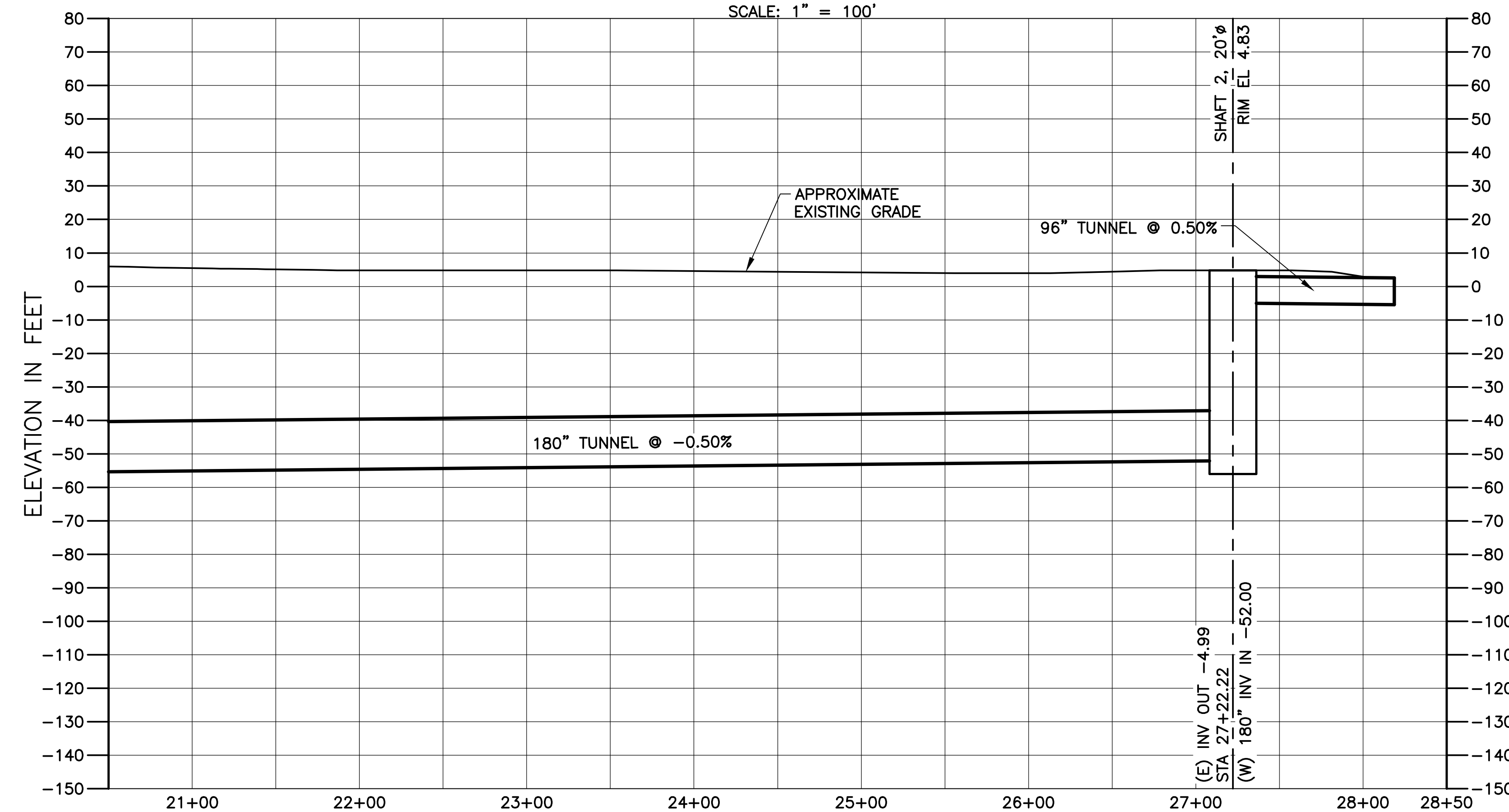
TUNNEL CONFIGURATION ALTERNATIVE T4

DRAWING: C1



PLAN

SCALE: 1" = 100'



PROFILE

SCALE: 1" = 100' HORIZONTAL
1" = 50' VERTICAL

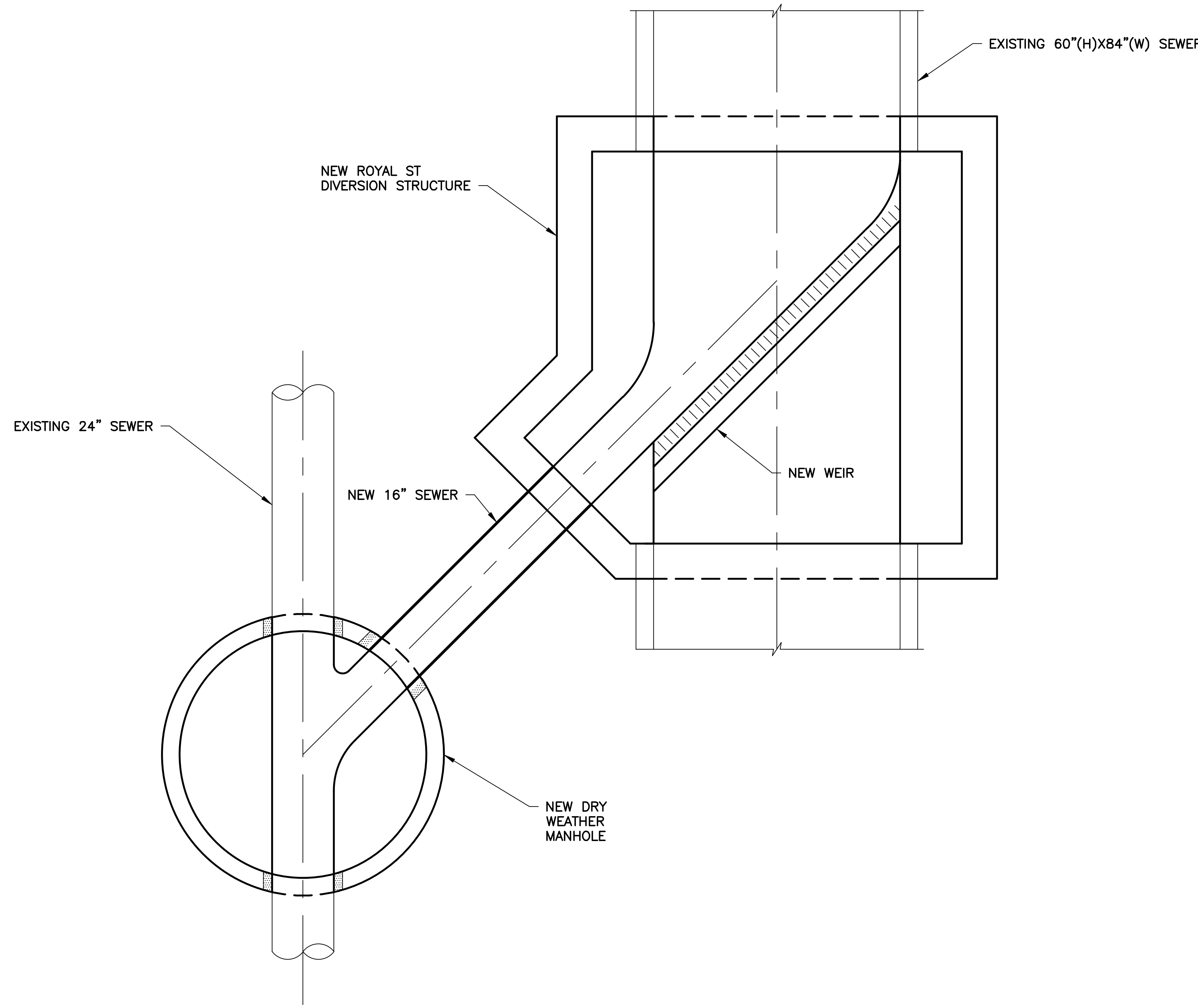
X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T4-C02.DWG 03/09/2015 10:30:32 AM

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

0 50 100 FT 1"=100'
0 50 FT 1"=50'

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T4
DRAWING: C2



PLAN

DETAIL 1/C3
ROYAL ST DIVERSION
NOT TO SCALE

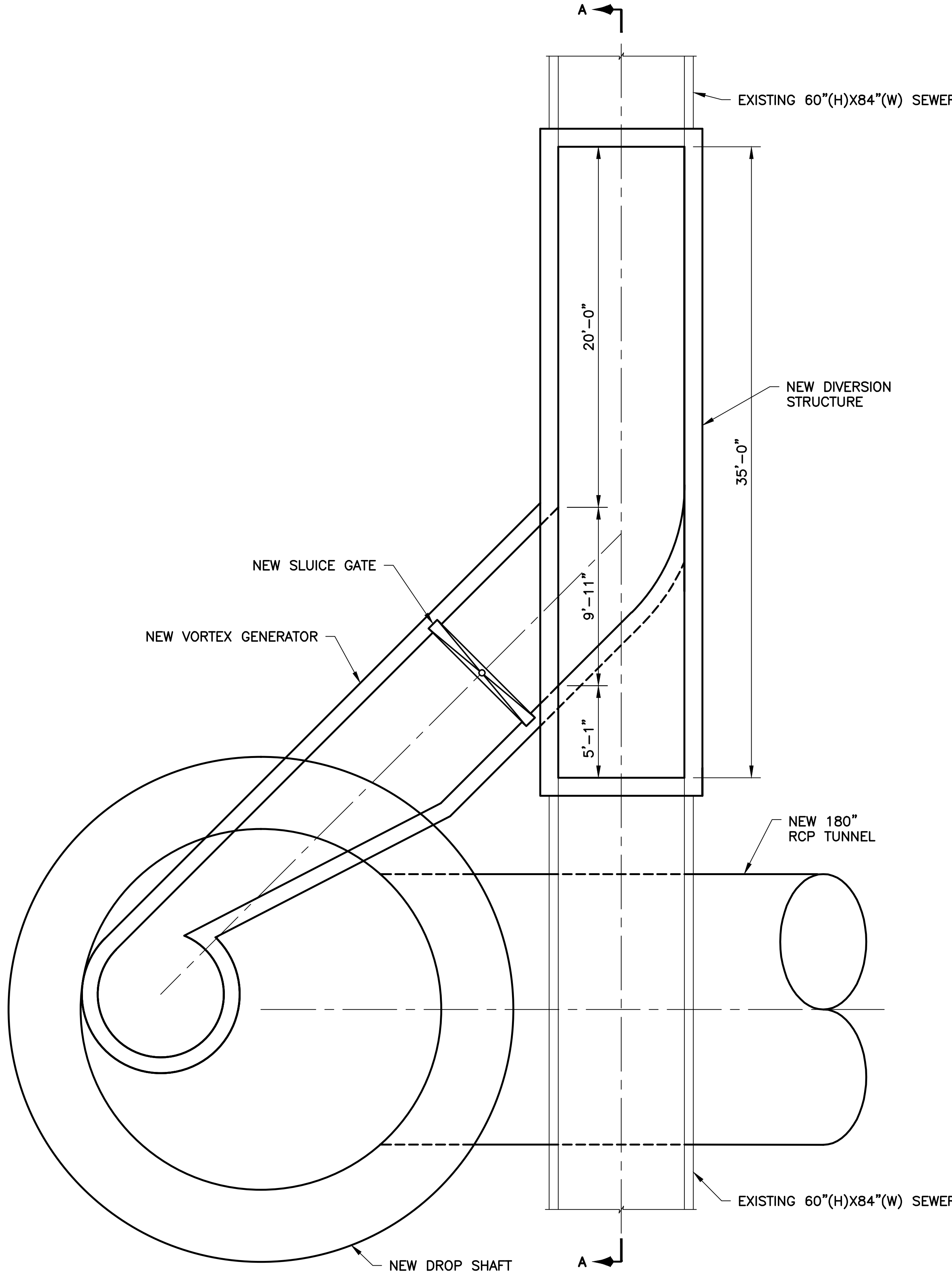
X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T4-C03.DWG 03/09/2015 10:29:16 AM

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

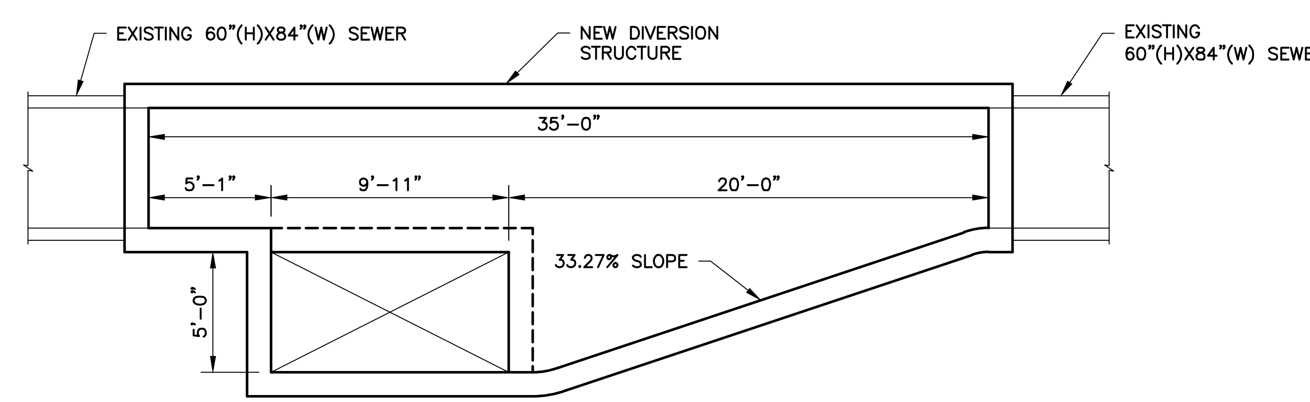
CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T4

DRAWING: C3



PLAN



SECTION A

DETAIL 1/C4
VORTEX GENERATOR AND DIVERSION STRUCTURE
NOT TO SCALE

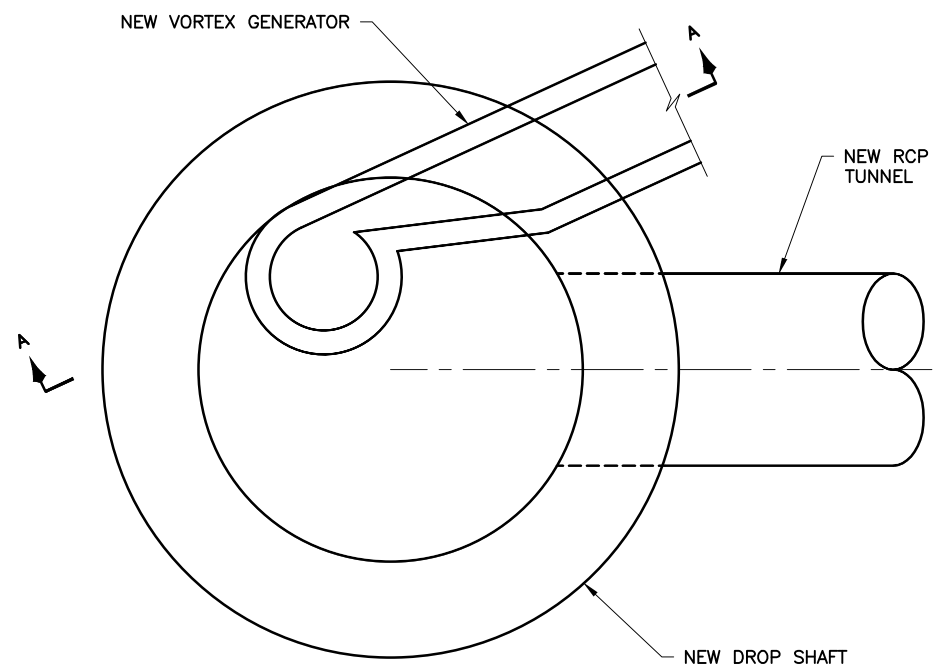
X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T4-C04.DWG 03/09/2015 10:45:19 AM

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

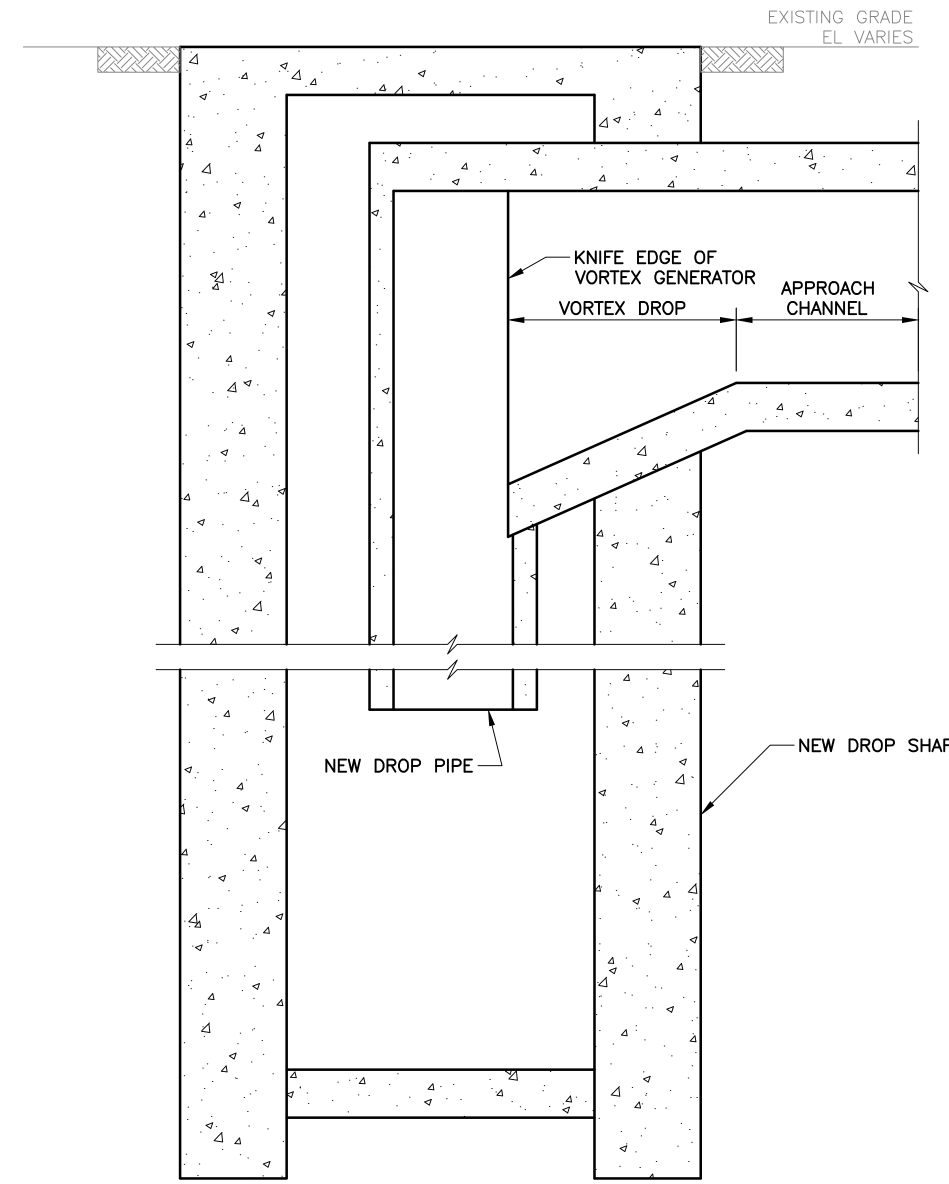
CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T4

DRAWING: C4



PLAN



SECTION A

DETAIL 1/C5
TYPICAL DROP SHAFT
AND VORTEX GENERATOR

NOT TO SCALE

X:\0057E-CSS\TO E13-02\21 CADD\21.05 WORKING DWGS\0057E.02-T4-C05.DWG 03/09/2015 10:27:51 AM

GREELEY AND HANSEN
5301 SHAWNEE ROAD, SUITE 400
ALEXANDRIA, VA 22312

CITY OF ALEXANDRIA
LTCP UPDATE
JANUARY 2015

TUNNEL CONFIGURATION ALTERNATIVE T4

DRAWING: C5

Attachment F

Tunnel Alternatives Cost Estimates

COA LTCPU
Summary

Date: 6-Mar-15
Prepared By: D. Dvorak
Checked By: J. McGettigan

Alternative	Construction	Project	Land	Total
TO-16	$35.2	$12.3	$1.1	$48.6
T1-A	$44.0	$15.4	$1.1	$60.5
T1-B	$108.9	$38.1	$1.1	$148.1
T2-A	$78.2	$27.4	$1.1	$106.6
T2-B	$224.9	$78.7	$1.1	$304.7
T3-A	$84.7	$29.6	$3.3	$117.6
T3-B	$255.4	$89.4	$3.3	$348.0
T4-A	$24.6	$8.6	$1.6	$34.8
T4-B	$87.4	$30.6	$1.6	$119.7

Alternative	Annual O&M
TO-16	$0.4
T1-A	$0.6
T1-B	$1.5
T2-A	$1.2
T2-B	$3.2
T3-A	$1.2
T3-B	$3.5
T4-A	$0.5
T4-B	$1.5

Alternative	Project Costs	O&M NPW	N/P/TSS NPW	NPW
TO-16	$48.6	$5.9	-$0.7	$53.9
T1-A	$60.5	$8.5	-$2.2	$66.8
T1-B	$148.1	$21.6	-$6.8	$162.9
T2-A	$106.6	$17.6	-$7.5	$116.7
T2-B	$304.7	$47.5	-$18.1	$334.1
T3-A	$117.6	$18.5	-$7.5	$128.6
T3-B	$348.0	$52.1	-$18.1	$382.0
T4-A	$34.8	$7.7	-$5.3	$37.2
T4-B	$119.7	$21.7	-$11.3	$130.0

Alternative T1-A
Date: 6-Mar-15
Prepared By: D. Dvorak
Checked By: J. McGettigan

Item	QTY	Units	Unit Cost	Total	Comments
003/004 Tunnel					
8' Tunnel from Dangerfield Road to NMF	2,600	LF	$3,600	$9,360,000	Guidance From Jacobs
Shaft 1 (15' diameter)	75	VLF	$26,000	$1,950,000	Guidance From Jacobs
Shaft 2 (20' diameter)	80	VLF	$32,000	$2,560,000	Guidance From Jacobs
Shaft 3 (20' diameter)	90	VLF	$32,000	$2,880,000	Guidance From Jacobs
Shaft 4 (15' diameter)	100	VLF	$26,000	$2,600,000	Guidance From Jacobs
8' Tunnel from CI to NMF	400	LF	$3,600	$1,440,000	Guidance From Jacobs
Diversion Structures	2	EA	$600,000	$1,200,000	Local Project Data (K&W)
48" Sewer	300	LF	$1,200	$360,000	DC LTCP
				$22,350,000	
Facilities					
Odor Control	1	EA	$500,000.0	$500,000	Allowance
Dewatering PS	1.0	MGD	Equation	$650,000	Cost Curve
Wet Weather PS	1	LS	$7,100,000	$7,100,000	TO-16 Estimate
Climber Screens	1	LS	$2,000,000	$2,000,000	Allowace
				$10,250,000	
Subtotal				*$32,600,000*	
Construction Contingency	35%			$11,410,000	
Construction Subtotal				$44,010,000	
Planning, Design, Construction Management, Administration, Permitting and Easements	35%			$15,403,500	
Land Acquisition	14,520	SF	$125	$1,090,000	
Total Project				**$60,503,500**	

Table 2: Operational and Maintenance Cost Estimate

Item	QTY	Units	Unit Cost	Total	Comments
Operational Cost					
Treatment Cost at AlexRenew	15.3	MGY	$ 6.44	$ 98,468	$6.44/1,000 Gallons
Pumping Costs	8,102	kw-hrs	$ 0.08	$ 648.2	
Annual Volume	15.3	MGY			
Total Dynamic Head	90	ft			
Pump Efficiency	0.6				
Motor Efficiency	0.9				
Washdown Water (10% Tunnel Volume x 4)	400	TG	$ 4.00	$ 1,600	
Labor Costs	576	Hrs	$ 50.00	$ 28,800	
Monthly Inspections (12@16hrs/each)	192	Hrs			
Quarterly Cleaning (4@96hrs/each)	384	Hrs			
Maintenance Costs					
Percentage of Construction	1.00%			$ 440,100	DC LTCP Assumption
Annual O&M				$ 569,616	
Net Present Worth				**$ 8,474,444**	

Table 3: Stormwater Nutrient and Sediment Costs

Item	QTY	Units	Unit Cost	Total	Comments
Annual Volume	15.3	MGY			
Total Suspended Solids					
TMDL Concentration	70.50	mg/L			
Dischage Concentration	6.0	mg/L			
Removed	64.50	mg/L			
Load	8225	lbs/yr	$80	$ 657,996	
Nitrogen					
TMDL Concentration	5.88	mg/L			
Dischage Concentration	3.0	mg/L			
Removed	2.88	mg/L			
Load	367	lbs/yr	$6,000	$ 2,203,521	
Phosphorous					
TMDL Concentration	0.78	mg/L			
Dischage Concentration	0.18	mg/L			
Removed	0.60	mg/L			
Load	77	lbs/yr	$25,000	$ 1,912,779	
Net Present Worth				$ 2,203,521	

Alternative	T1-B
Date:	6-Mar-15
Prepared By:	D. Dvorak
Checked By:	J. McGettigan

Item	QTY	Units	Unit Cost	Total	Comments
003/004 Tunnel					
34' Tunnel from Dangerfield Road to NMF	2,600	LF	$14,100	$36,660,000	Cost Curve
Shaft 1 (45' diameter)	75	VLF	$59,500	$4,462,500	Cost Curve
Shaft 2 (70' diameter)	80	VLF	$87,000	$6,960,000	Cost Curve
Shaft 3 (70' diameter)	90	VLF	$87,000	$7,830,000	Cost Curve
Shaft 4 (45' diameter)	100	VLF	$59,500	$5,950,000	Cost Curve
8' Tunnel from CI to NMF	400	LF	$3,600	$1,440,000	Guidance From Jacobs
Diversion Structures	2	EA	$600,000	$1,200,000	Local Project Data (K&W)
48" Sewer	300	LF	$1,200	$360,000	DC LTCP
				$64,862,500	
Facilities					
Odor Control	1	EA	$500,000.0	$500,000	Allowance
Dewatering PS	18.0	MGD	Equation	$6,190,000	Cost Curve
Wet Weather PS	1	LS	$7,100,000	$7,100,000	TO-16 Estimate
Climber Screens	1	LS	$2,000,000	$2,000,000	Allowace
				$15,790,000	
Subtotal				*$80,652,500*	
Construction Contingency	35%			$28,228,375	
Construction Subtotal				$108,880,875	
Planning, Design, Construction Management, Administration, Permitting and Easements	35%			$38,108,306	
Land Acquisition	21,780	SF	$125	$1,090,000	
Total Project				**$148,079,181**	

Table 2: Operational and Maintenance Cost Estimate

Item	QTY	Units	Unit Cost	Total	Comments
Operational Cost					
Treatment Cost at AlexRenew	46.9	MGY	$ 6.44	$ 302,294	$6.44/1,000 Gallons
Pumping Costs	24,873	kw-hrs	$ 0.08	$ 1,989.9	
Annual Volume	46.9	MGY			
Total Dynamic Head	90	ft			
Pump Efficiency	0.6				
Motor Efficiency	0.9				
Washdown Water (10% Tunnel Volume x 4)	7,116	TG	$ 4.00	$ 28,464	
Labor Costs	576	Hrs	$ 50.00	$ 28,800	
Monthly Inspections (12@16hrs/each)	192	Hrs			
Quarterly Cleaning (4@96hrs/each)	384	Hrs			
Maintenance Costs					
Percentage of Construction	1.00%			$ 1,088,809	DC LTCP Assumption
Annual O&M				$ 1,450,356	
Net Present Worth				**$ 21,577,638**	

Table 3: Stormwater Nutrient and Sediment Costs

Item	QTY	Units	Unit Cost	Total	Comments
Annual Volume	46.9	MGY			
Total Suspended Solids					
TMDL Concentration	70.50	mg/L			
Dischage Concentration	6.0	mg/L			
Removed	64.50	mg/L			
Load	25250	lbs/yr	$80	$ 2,020,035	
Nitrogen					
TMDL Concentration	5.88	mg/L			
Dischage Concentration	3.0	mg/L			
Removed	2.88	mg/L			
Load	1127	lbs/yr	$6,000	$ 6,764,767	
Phosphorous					
TMDL Concentration	0.78	mg/L			
Dischage Concentration	0.18	mg/L			
Removed	0.60	mg/L			
Load	235	lbs/yr	$25,000	$ 5,872,194	
Net Present Worth				$ 6,764,767	

Alternative T2-A
Date: 6-Mar-15
Prepared By: D. Dvorak
Checked By: J. McGettigan

Item	QTY	Units	Unit Cost	Total	Comments
003/004 Tunnel					
8' Tunnel from Dangerfield Road to NMF	2,600	LF	$3,600	$9,360,000	Guidance From Jacobs
Shaft 1 (15' diameter)	75	VLF	$26,000	$1,950,000	Guidance From Jacobs
Shaft 2 (20' diameter)	80	VLF	$32,000	$2,560,000	Guidance From Jacobs
Shaft 3 (20' diameter)	90	VLF	$32,000	$2,880,000	Guidance From Jacobs
Shaft 4 (15' diameter)	100	VLF	$26,000	$2,600,000	Guidance From Jacobs
8' Tunnel from CI to NMF	400	LF	$3,600	$1,440,000	Guidance From Jacobs
Diversion Structures	2	EA	$600,000	$1,200,000	Local Project Data (K&W)
48" Sewer	300	LF	$1,200	$360,000	DC LTCP
				$22,350,000	
002 Tunnel					
8' Tunnel from Royal Street to NMF	4,800	LF	$3,600	$17,280,000	Guidance From Jacobs
Shaft 5 (20' diameter)	120	VLF	$32,000	$3,840,000	Guidance From Jacobs
Shaft 6 (20' diameter)	70	VLF	$32,000	$2,240,000	Guidance From Jacobs
Diversion Structures	1	EA	$600,000	$600,000	Local Project Data (K&W)
72" Sewer	100	LF	$1,700	$170,000	DC LTCP
				$24,130,000	
Facilities					
Odor Control	2	EA	$500,000	$1,000,000	Allowance
Dewatering PS	3.0	MGD	Equation	$1,310,000	Cost Curve
Wet Weather PS	1	LS	$7,100,000	$7,100,000	TO-16 Estimate
Climber Screens	1	LS	$2,000,000	$2,000,000	Allowance
				$11,410,000	
Subtotal				*$57,890,000*	
Construction Contingency	35%			$20,261,500	
Construction Subtotal				$78,151,500	
Planning, Design, Construction Management, Administration, Permitting and Easements	35%			$27,353,025	
Land Acquisition	14,520	SF	$100	$1,090,000	
Total Project				**$106,594,525**	

Table 2: Operational and Maintenance Cost Estimate

Item	QTY	Units	Unit Cost	Total	Comments
Operational Cost					
Treatment Cost at AlexRenew	52.1	MGY	$ 6.44	$ 335,460	$6.44/1,000 Gallons
Pumping Costs	27,602	kw-hrs	$ 0.08	$ 2,208.2	
Annual Volume	52.1	MGY			
Total Dynamic Head	90	ft			
Pump Efficiency	0.6				
Motor Efficiency	0.9				
Washdown Water (10% Tunnel Volume x 4)	1,200	TG	$ 4.00	$ 4,800	
Labor Costs	1152	Hrs	$ 50.00	$ 57,600	
Monthly Inspections (12@32hrs/each)	384	Hrs			
Quarterly Cleaning (4@192hrs/each)	768	Hrs			
Maintenance Costs					
Percentage of Construction	1.00%			$ 781,515	DC LTCP Assumption
Annual O&M				$ 1,181,583	
Net Present Worth				**$ 17,578,968**	

Table 3: Stormwater Nutrient and Sediment Costs

Item	QTY	Units	Unit Cost	Total	Comments
Annual Volume	52.1	MGY			
Total Suspended Solids					
TMDL Concentration	70.50	mg/L			
Dischage Concentration	6.0	mg/L			
Removed	64.50	mg/L			
Load	28021	lbs/yr	$80	$ 2,241,662	
Nitrogen					
TMDL Concentration	5.88	mg/L			
Dischage Concentration	3.0	mg/L			
Removed	2.88	mg/L			
Load	1251	lbs/yr	$6,000	$ 7,506,961	
Phosphorous					
TMDL Concentration	0.78	mg/L			
Dischage Concentration	0.18	mg/L			
Removed	0.60	mg/L			
Load	261	lbs/yr	$25,000	$ 6,516,459	
Net Present Worth				$ 7,506,961	

COA LTCPU
T2-B

Alternative T2-B
Date: 6-Mar-15
Prepared By: D. Dvorak
Checked By: J. McGettigan

Item	QTY	Units	Unit Cost	Total	Comments
003/004 Tunnel					
32' Tunnel from Dangerfield Road to NMF	2,600	LF	$13,000	$33,800,000	Cost Curve
Shaft 1 (45' diameter)	75	VLF	$59,500	$4,462,500	Cost Curve
Shaft 2 (70' diameter)	80	VLF	$87,000	$6,960,000	Cost Curve
Shaft 3 (70' diameter)	90	VLF	$87,000	$7,830,000	Cost Curve
Shaft 4 (45' diameter)	100	VLF	$59,500	$5,950,000	Cost Curve
8' Tunnel from CI to NMF	400	LF	$3,600	$1,440,000	Guidance From Jacobs
Diversion Structures	2	EA	$600,000	$1,200,000	Local Project Data (K&W)
48" Sewer	300	LF	$1,200	$360,000	DC LTCP
				$62,002,500	
002 Tunnel					
32' Tunnel from Royal Street to NMF	4,800	LF	$13,000	$62,400,000	Cost Curve
Shaft 5 (70' diameter)	120	VLF	$87,000	$10,440,000	Cost Curve
Shaft 6 (70' diameter)	70	VLF	$87,000	$6,090,000	Cost Curve
Diversion Structures	1	EA	$600,000	$600,000	Local Project Data (K&W)
72" Sewer	100	LF	$1,700	$170,000	DC LTCP
				$79,700,000	
Facilities					
Odor Control	2	EA	$500,000	$1,000,000	Allowance
Dewatering PS	45.0	MGD	Equation	$14,780,000	Cost Curve
Wet Weather PS	1	LS	$7,100,000	$7,100,000	TO-16 Estimate
Climber Screens	1	LS	$2,000,000	$2,000,000	Allowace
				$24,880,000	
Subtotal				*$166,582,500*	
Construction Contingency	35%			$58,303,875	
Construction Subtotal				$224,886,375	
Planning, Design, Construction Management, Administration, Permitting and Easements	35%			$78,710,231	
Land Acquisition	14,520	SF	$100	$1,090,000	
Total Project				**$304,686,606**	

Table 2: Operational and Maintenance Cost Estimate

Item	QTY	Units	Unit Cost	Total	Comments
Operational Cost					
Treatment Cost at AlexRenew	125.6	MGY	$ 6.44	$ 808,735	$6.44/1,000 Gallons
Pumping Costs	66,544	kw-hrs	$ 0.08	$ 5,323.5	
Annual Volume	125.6	MGY			
Total Dynamic Head	90	ft			
Pump Efficiency	0.6				
Motor Efficiency	0.9				
Washdown Water (10% Tunnel Volume x 4)	18,652	TG	$ 4.00	$ 74,608	
Labor Costs	1152	Hrs	$ 50.00	$ 57,600	
Monthly Inspections (12@32hrs/each)	384	Hrs			
Quarterly Cleaning (4@192hrs/each)	768	Hrs			
Maintenance Costs					
Percentage of Construction	1.00%			$ 2,248,864	DC LTCP Assumption
Annual O&M				$ 3,195,130	
Net Present Worth				**$ 47,535,473**	

Table 3: Stormwater Nutrient and Sediment Costs

Item	QTY	Units	Unit Cost	Total	Comments
Annual Volume	125.6	MGY			
Total Suspended Solids					
TMDL Concentration	70.50	mg/L			
Dischage Concentration	6.0	mg/L			
Removed	64.50	mg/L			
Load	67553	lbs/yr	$80	$ 5,404,260	
Nitrogen					
TMDL Concentration	5.88	mg/L			
Dischage Concentration	3.0	mg/L			
Removed	2.88	mg/L			
Load	3016	lbs/yr	$6,000	$ 18,097,987	
Phosphorous					
TMDL Concentration	0.78	mg/L			
Dischage Concentration	0.18	mg/L			
Removed	0.60	mg/L			
Load	628	lbs/yr	$25,000	$ 15,710,058	
Net Present Worth				$ 18,097,987	

Alternative T3-A
Date: 6-Mar-15
Prepared By: D. Dvorak
Checked By: J. McGettigan

Item	QTY	Units	Unit Cost	Total	Comments
003/004 Tunnel					
8' Tunnel from Dangerfield Road to NMF	2,600	LF	$3,600	$9,360,000	Guidance From Jacobs
Shaft 1 (15' diameter)	75	VLF	$26,000	$1,950,000	Guidance From Jacobs
Shaft 2 (20' diameter)	80	VLF	$32,000	$2,560,000	Guidance From Jacobs
Shaft 3 (20' diameter)	90	VLF	$32,000	$2,880,000	Guidance From Jacobs
8' Tunnel from CI to NMF	0	LF	$3,600	$0	Guidance From Jacobs
Diversion Structures	2	EA	$600,000	$1,200,000	Local Project Data (K&W)
48" Sewer	300	LF	$1,200	$360,000	DC LTCP
				$18,310,000	
002 Tunnel					
8' Tunnel from Royal Street to NMF	6,500	LF	$3,600	$23,400,000	Guidance From Jacobs
Shaft 5 (20' diameter)	120	VLF	$32,000	$3,840,000	Guidance From Jacobs
Shaft 6 (20' diameter)	70	VLF	$32,000	$2,240,000	Guidance From Jacobs
Shaft 7 (20' diameter)	60	VLF	$32,000	$1,920,000	Guidance From Jacobs
Diversion Structures	1	EA	$600,000	$600,000	Local Project Data (K&W)
72" Sewer	100	LF	$1,700	$170,000	DC LTCP
				$32,170,000	
Facilities					
Odor Control	3	EA	$500,000	$1,500,000	Allowance
Dewatering PS	4.0	MGD	Equation	$1,630,000	Cost Curve
Wet Weather PS	1	LS	$7,100,000	$7,100,000	TO-16 Estimate
Climber Screens	1	LS	$2,000,000	$2,000,000	Allowace
				$12,230,000	
Subtotal				*$62,710,000*	
Construction Contingency	35%			$21,948,500	
Construction Subtotal				$84,658,500	
Planning, Design, Construction Management, Administration, Permitting and Easements	35%			$29,630,475	
Land Acquisition	43,560	SF	$100	$3,270,000	
Total Project				**$117,558,975**	

Table 2: Operational and Maintenance Cost Estimate

Item	QTY	Units	Unit Cost	Total	Comments
Operational Cost					
Treatment Cost at AlexRenew	52.1	MGY	$ 6.44	$ 335,524	$6.44/1,000 Gallons
Pumping Costs	27,607	kw-hrs	$ 0.08	$ 2,208.6	
Annual Volume	52.1	MGY			
Total Dynamic Head	90	ft			
Pump Efficiency	0.6				
Motor Efficiency	0.9				
Washdown Water (10% Tunnel Volume x 4)	1,200	TG	$ 4.00	$ 4,800	
Labor Costs	1152	Hrs	$ 50.00	$ 57,600	
Monthly Inspections (12@32hrs/each)	384	Hrs			
Quarterly Cleaning (4@192hrs/each)	768	Hrs			
Maintenance Costs					
Percentage of Construction	1.00%			$ 846,585	DC LTCP Assumption
Annual O&M				$ 1,246,718	
Net Present Worth				**$ 18,548,010**	

Table 3: Stormwater Nutrient and Sediment Costs

Item	QTY	Units	Unit Cost	Total	Comments
Annual Volume	52.1	MGY			
Total Suspended Solids					
TMDL Concentration	70.50	mg/L			
Dischage Concentration	6.0	mg/L			
Removed	64.50	mg/L			
Load	28026	lbs/yr	$80	$ 2,242,092	
Nitrogen					
TMDL Concentration	5.88	mg/L			
Dischage Concentration	3.0	mg/L			
Removed	2.88	mg/L			
Load	1251	lbs/yr	$6,000	$ 7,508,402	
Phosphorous					
TMDL Concentration	0.78	mg/L			
Dischage Concentration	0.18	mg/L			
Removed	0.60	mg/L			
Load	261	lbs/yr	$25,000	$ 6,517,710	
Net Present Worth				$ 7,508,402	

Alternative T3-B
Date: 6-Mar-15
Prepared By: D. Dvorak
Checked By: J. McGettigan

Item	QTY	Units	Unit Cost	Total	Comments
003/004 Tunnel					
32' Tunnel from Dangerfield Road to NMF	2,600	LF	$13,000	$33,800,000	Cost Curve
Shaft 1 (45' diameter)	75	VLF	$59,500	$4,462,500	Cost Curve
Shaft 2 (70' diameter)	80	VLF	$87,000	$6,960,000	Cost Curve
Shaft 3 (70' diameter)	90	VLF	$87,000	$7,830,000	Cost Curve
8' Tunnel from CI to NMF	0	LF	$3,600	$0	Guidance From Jacobs
Diversion Structures	2	EA	$600,000	$1,200,000	Local Project Data (K&W)
48" Sewer	300	LF	$1,200	$360,000	DC LTCP
				$54,612,500	
002 Tunnel					
32' Tunnel from Royal Street to NMF	6,500	LF	$13,000	$84,500,000	Cost Curve
Shaft 5 (70' diameter)	120	VLF	$87,000	$10,440,000	Cost Curve
Shaft 6 (70' diameter)	70	VLF	$87,000	$6,090,000	Cost Curve
Shaft 7 (70' diameter)	60	VLF	$87,000	$5,220,000	Guidance From Jacobs
Diversion Structures	1	EA	$600,000	$600,000	Local Project Data (K&W)
72" Sewer	100	LF	$2,000	$200,000	DC LTCP
				$107,050,000	
Facilities					
Odor Control	3	EA	$500,000	$1,500,000	Allowance
Dewatering PS	55.0	MGD	Equation	$17,890,000	Cost Curve
Wet Weather PS	1	LS	$7,100,000	$7,100,000	TO-16 Estimate
Climber Screens	1	LS	$2,000,000	$1,000,000	Allowace
				$27,490,000	
Subtotal				*$189,152,500*	
Construction Contingency	35%			$66,203,375	
Construction Subtotal				$255,355,875	
Planning, Design, Construction Management, Administration, Permitting and Easements	35%			$89,374,556	
Land Acquisition	87,120	SF	$100	$3,270,000	
Total Project				**$348,000,431**	

Table 2: Operational and Maintenance Cost Estimate

Item	QTY	Units	Unit Cost	Total	Comments
Operational Cost					
Treatment Cost at AlexRenew	125.6	MGY	$ 6.44	$ 808,735	$6.44/1,000 Gallons
Pumping Costs	66,544	kw-hrs	$ 0.08	$ 5,323.5	
Annual Volume	125.6	MGY			
Total Dynamic Head	90	ft			
Pump Efficiency	0.6				
Motor Efficiency	0.9				
Washdown Water (10% Tunnel Volume x 4)	18,652	TG	$ 4.00	$ 74,608	
Labor Costs	1152	Hrs	$ 50.00	$ 57,600	
Monthly Inspections (12@32hrs/each)	384	Hrs			
Quarterly Cleaning (4@192hrs/each)	768	Hrs			
Maintenance Costs					
Percentage of Construction	1.00%			$ 2,553,559	DC LTCP Assumption
Annual O&M				$ 3,499,825	
Net Present Worth				**$ 52,068,565**	

Table 3: Stormwater Nutrient and Sediment Costs

Item	QTY	Units	Unit Cost	Total	Comments
Annual Volume	125.6	MGY			
Total Suspended Solids					
TMDL Concentration	70.50	mg/L			
Dischage Concentration	6.0	mg/L			
Removed	64.50	mg/L			
Load	67553	lbs/yr	$80	$ 5,404,260	
Nitrogen					
TMDL Concentration	5.88	mg/L			
Dischage Concentration	3.0	mg/L			
Removed	2.88	mg/L			
Load	3016	lbs/yr	$6,000	$ 18,097,987	
Phosphorous					
TMDL Concentration	0.78	mg/L			
Dischage Concentration	0.18	mg/L			
Removed	0.60	mg/L			
Load	628	lbs/yr	$25,000	$ 15,710,058	
Net Present Worth				$ 18,097,987	

Alternative T4-A
Date: 6-Mar-15
Prepared By: D. Dvorak
Checked By: J. McGettigan

Item	QTY	Units	Unit Cost	Total	Comments
002 Tunnel					
15' Tunnel from Royal St to Potomac River	1,700	LF	$6,000	$10,200,000	Cost Curve
Shaft 6 (30' diameter)	70	VLF	$43,000	$3,010,000	Cost Curve
Shaft 7 (30' diameter)	60	VLF	$43,000	$2,580,000	Cost Curve
Diversion Structures	1	EA	$600,000	$600,000	Cost Curve
72" Sewer	100	LF	$1,700	$170,000	DC LTCP
				$16,560,000	
Facilities					
Odor Control	1	EA	$500,000	$500,000	Allowance
Dewatering PS	2.5	MGD	Equation	$1,140,000	Cost Curve
Wet Weather PS	0	LS	$7,100,000	$0	TO-16 Estimtate
Climber Screens	0	LS	$2,000,000	$0	Allowace
				$1,640,000	
Subtotal				*$18,200,000*	
Construction Contingency	35%			$6,370,000	
Construction Subtotal				$24,570,000	
Planning, Design, Construction Management, Administration, Permitting and Easements	35%			$8,599,500	
Land Acquisition	21,780	SF	$75	$1,630,000	
Total Project				**$34,799,500**	

Table 2: Operational and Maintenance Cost Estimate

Item	QTY	Units	Unit Cost	Total	Comments
Operational Cost					
Treatment Cost at AlexRenew	36.8	MGY	$ 6.44	$ 236,992	$6.44/1,000 Gallons
Pumping Costs	19,500	kw-hrs	$ 0.08	$ 1,560.0	
Annual Volume	36.8	MGY			
Total Dynamic Head	90	ft			
Pump Efficiency	0.6				
Motor Efficiency	0.9				
Washdown Water (10% Tunnel Volume x 4)	800	TG	$ 4.00	$ 3,200	
Labor Costs	576	Hrs	$ 50.00	$ 28,800	
Monthly Inspections (12@16hrs/each)	192	Hrs			
Quarterly Cleaning (4@96hrs/each)	384	Hrs			
Maintenance Costs					
Percentage of Construction	1.00%			$ 245,700	DC LTCP Assumption
Annual O&M				$ 516,252	
Net Present Worth				**$ 7,680,526**	

Table 3: Stormwater Nutrient and Sediment Costs

Item	QTY	Units	Unit Cost	Total	Comments
Annual Volume	36.8	MGY			
Total Suspended Solids					
TMDL Concentration	70.50	mg/L			
Dischage Concentration	6.0	mg/L			
Removed	64.50	mg/L			
Load	19796	lbs/yr	$80	$ 1,583,666	
Nitrogen					
TMDL Concentration	5.88	mg/L			
Dischage Concentration	3.0	mg/L			
Removed	2.88	mg/L			
Load	884	lbs/yr	$6,000	$ 5,303,439	
Phosphorous					
TMDL Concentration	0.78	mg/L			
Dischage Concentration	0.18	mg/L			
Removed	0.60	mg/L			
Load	184	lbs/yr	$25,000	$ 4,603,680	
Net Present Worth				$ 5,303,439	

Alternative T4-B
Date: 6-Mar-15
Prepared By: D. Dvorak
Checked By: J. McGettigan

Item	QTY	Units	Unit Cost	Total	Comments
002 Tunnel					
51' Tunnel from Royal St to Potomac River	1,700	LF	$24,700	$41,990,000	Cost Curve
Shaft 6 (80' diameter)	70	VLF	$98,000	$6,860,000	Cost Curve
Shaft 7 (80' diameter)	60	VLF	$98,000	$5,880,000	Cost Curve
Diversion Structures	1	EA	$600,000	$600,000	Cost Curve
72" Sewer	100	LF	$1,700	$170,000	DC LTCP
				$55,500,000	
Facilities					
Odor Control	1	EA	$500,000	$500,000	Allowance
Dewatering PS	26.0	MGD	Equation	$8,770,000	Cost Curve
Wet Weather PS	0	LS	$7,100,000	$0	TO-16 Estimate
Climber Screens	0	LS	$2,000,000	$0	Allowace
				$9,270,000	
Subtotal				*$64,770,000*	
Construction Contingency	35%			$22,669,500	
Construction Subtotal				$87,439,500	
Planning, Design, Construction Management, Administration, Permitting and Easements	35%			$30,603,825	
Land Acquisition	87,120	SF	$75	$1,630,000	
Total Project				**$119,673,325**	

Table 2: Operational and Maintenance Cost Estimate

Item	QTY	Units	Unit Cost	Total	Comments
Operational Cost					
Treatment Cost at AlexRenew	78.6	MGY	$ 6.44	$ 506,442	$6.44/1,000 Gallons
Pumping Costs	41,671	kw-hrs	$ 0.08	$ 3,333.7	
Annual Volume	78.6	MGY			
Total Dynamic Head	90	ft			
Pump Efficiency	0.6				
Motor Efficiency	0.9				
Washdown Water (10% Tunnel Volume x 4)	11,536	TG	$ 4.00	$ 46,144	
Labor Costs	576	Hrs	$ 50.00	$ 28,800	
Monthly Inspections (12@16hrs/each)	192	Hrs			
Quarterly Cleaning (4@96hrs/each)	384	Hrs			
Maintenance Costs					
Percentage of Construction	1.00%			$ 874,395	DC LTCP Assumption
Annual O&M				$ 1,459,114	
Net Present Worth				**$ 21,707,936**	

Table 3: Stormwater Nutrient and Sediment Costs

Item	QTY	Units	Unit Cost	Total	Comments
Annual Volume	78.6	MGY			
Total Suspended Solids					
TMDL Concentration	70.50	mg/L			
Dischage Concentration	6.0	mg/L			
Removed	64.50	mg/L			
Load	42303	lbs/yr	$80	$ 3,384,225	
Nitrogen					
TMDL Concentration	5.88	mg/L			
Dischage Concentration	3.0	mg/L			
Removed	2.88	mg/L			
Load	1889	lbs/yr	$6,000	$ 11,333,219	
Phosphorous					
TMDL Concentration	0.78	mg/L			
Dischage Concentration	0.18	mg/L			
Removed	0.60	mg/L			
Load	394	lbs/yr	$25,000	$ 9,837,864	
Net Present Worth				$ 11,333,219	

Greeley and Hansen LLC
5301 Shawnee Road
Alexandria, VA 22312
571.581.3000
www.greeley-hansen.com

GREELEY AND HANSEN